PHD

Decision support and expert systems technologies applied to production scheduling in the garment manufacturing industry: A study of three cases

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Award date:
1992

Awarding institution:
University of Bath

DECISION SUPPORT AND EXPERT SYSTEMS TECHNOLOGIES
APPLIED TO PRODUCTION SCHEDULING
IN THE GARMENT MANUFACTURING INDUSTRY
A Study of Three Cases

submitted by J.E. Peterson
For the Degree of Ph.D
Of the University of Bath
1991

ACKNOWLEDGEMENTS

This journey began in 1983, as a result of encouragement from the Faculty of Administrative Studies, University of Manitoba and especially Dr. Ken Clowes, and Dr. Jerry Gray. Dr. Ross Henderson and Dr. Yash Gupta also supported my continuing study. The understanding and accommodation by the garment manufacturing industry in Canada, the U.K. and Finland, has been instrumental in the completion of this work. Of great value to me was the opportunity to visit with the management of Alexandra in the U.K., and, Pola Paita and Verke in Finland. To my colleagues in Eriksson Associates in Helsinki, I am most grateful for their assistance, encouragement and friendship.

The support, and good wishes of my many friends and associates in Canada has also been deeply appreciated.

In Bath, I met fellow students who alone understand what this process is all about. I commend them for their encouragement, assistance and friendship. To my supervisor, Dr. Rod Green, and my viva committee; Dr. P. Sims and Dr. J. Bryant, whose high standards I applaud, I can only say thank you.

My business partners in Infocorp Computer Solutions and CAASS Inc. have been very understanding and supportative, and I am deeply grateful.

Finally, I owe my wife and family more then I shall ever be able to repay for their support, sacrifice, and patience. I thank God for all this help and for His guidance.

ABSTRACT

This thesis is a study of the application of Decision Support and Expert Systems technologies to production scheduling in the Garment Manufacturing Industry(GMI). The importance of the scheduling function to the GMI justifies the search for better systems and methodologies. The intent is to provide management, system developers and researchers with insight that will help them in their quest for better scheduling systems.

Although Decision Support Systems(DSS) have been used in many applications, they are limited in their ability to solve scheduling problems. In recent years Expert Systems(ES) concepts have been applied to the scheduling problem. The resulting Expert Scheduling Systems(ESS) have showed promise in research environments but few operating systems are reported.

This study proposes that the individual limitations of DSS and ES technologies applied to the scheduling problem can be overcome by the merging of selected concepts from each field.

The study presents a discussion of how three garment manufacturers used micro computer based DSS and ES systems to attempt to improve their scheduling function. The three cases are examined from the viewpoints of the setting, design process, the actual design representations, and the results achieved from the use of the completed systems.

The results achieved suggest the importance of macro and micro organizational policies, selection of appropriate PC-based technologies, and the coupling of the scheduler's knowledge, activities and functions with system tools and

representations, in a merged DSS/ES environment.

As one of the central characters in the development of each of these systems, my role as both developer and researcher has presented both challenges and insights into such research methodology.

Future considerations are discussed from the viewpoints of a proposed architecture for expert scheduling systems, and, for future researchers, unanswered questions.

TABLE OF CONTENTS

PART I

CHAPTER 1 - INTRODUCTION

1.1. INTRODUCTION

At 1:00 p.m. the chairman's secretary informed us that our meeting was to begin. The new Director of Manufacturing and I entered the chairman's office. We walked by a large planter and climbed the three carpeted steps into the large office-apartment of the chairman of the company. Once seated in front of the sculptured desk, we waited for the completion of the telephone call which occupied the chairman. As the chairman lowered the telephone to the receiver, he turned and looking at both of us, asked "So you think you can solve our scheduling problem, do you?"

Thus began a journey which has taken me through years of work and thousands of miles attempting to solve this problem.

At the time the journey began, in 1984, I was an Associate Professor in the Department of Accounting and Finance in the Faculty of Administrative Studies at the University of Manitoba, Canada. Since 1981, I had been providing systems related consulting to a large Canadian garment manufacturing company. At about the time of my meeting with the chairman on the scheduling problem, I was in the process of enroling in the Ph.D program at the School of Management at the University of Bath. Dr. R. Green of the School of Management became my advisor. We shared a common interest in the emerging field of expert systems and their relationship to decision support systems(DSS). By Spring 1984, we had determined that the scheduling problem would be fertile ground for the study of the interface between DSS and Expert Systems.

1.2. CONTRIBUTION TO KNOWLEDGE

The purpose of this work is to enhance knowledge in the field defined by the union of the following areas:

1. The Production Scheduling Function, in
2. The Garment Manufacturing Industry, using
3. Computer Based Information Systems, in general, and
4. Decision Support Systems technology, and
5. Expert Systems technology, specifically.

In the thesis the Production Scheduling Function is studied in the literature and in three garment industry cases. The Scheduling Function is determined to be a process involving decision making. The quality of the decisions is seen in the quality of the schedules which determine a manufacturer's ability to deliver customer ordered products to customers by specific delivery dates, while operating at a profit. Thus Decision Support Systems(DSS) concepts are relevant.

The performance of the scheduling function is, in part, dependent upon the skill, experience and ability of the scheduler. This suggests that a scheduler, in making scheduling decisions, may possess expertise. The emerging field of Expert Systems(ES) addresses this area.

The problem studied is:

"the scheduling problem in the Garment Manufacturing Industry(GMI) "

The hypothesis proposed for solution of the problem is:

The merging of DSS and ES technologies results in successful(useful and usable) Garment Industry

Scheduling Systems.

The validity of this hypothesis is argued after consideration of evidence from the following sources:

1. DSS, ES and Information Technology literature.
2. Production scheduling literature.
3. Three case studies of the development of scheduling systems for three GMI companies.
4. Secondary application of ES Knowledge Analysis to the scheduling function.

This study draws heavily upon actual operational and management situations in the dynamic apparel industry. During the course of this study there have been many practical tests of the validity and usefulness of interim and final results. Many interim concepts have not passed the test of practical value. However, there have been several recognized successes which suggest that the effort has been worthy. Observations and Conclusions resulting from this study have been recognized in both research and industry circles as significant to the growth of knowledge in this field and of practical value to the Garment Manufacturing industry.

The study concludes that macro and micro organizational factors must create an environment for the subsequent successful implementation of components of DSS and ES technology to the GMI scheduling problem.

The success factors and their relationships are:

1. Consistency of management involvement,

   is essential to achieve:

2. Minimum project duration of 24 months,
3. Organization of the scheduling function, and

4. Continuity of the key players,

   while,

5. The Scheduler and his organizational prominence and technical skills,

   and

6. The small but capable development team,

   employ the methodology of

7. Prototyping of the scheduling system,

   to develop

8. The scheduling model and its DSS and ES system representations,

The study further concludes that the absence of any one of these 8 factors may lead to failure.

1.3. JUSTIFICATION FOR THE RESEARCH

The justification for the study of this field is encouraged by several sources, in both research and practice.

The general area of scheduling has been studied for many decades but continues to be lacking in widely acceptable practical solutions(Sen, Tapen and Gupta 1983).

Bensoussan, Crouhy and Proth(1983) have presented a thorough mathematical treatment of production planning and production smoothing problems using optimal control theory. Software programs representing their models suggest the promise of practical application. They claim that their concave and convex cost models "relate most closely to real life applications". However, their work is based on demand forecasts that are 1.5 times the length of the planning horizon, which are 1 to 2 years long. To avoid the real problems of inaccurate forecasts and short term demand fluctuations, they require the identification of some level of aggregation by product "family" with similar manufacturing requirements. This "family" must possess the property of accurate, and lengthy forecasts periods in order to utilize the proposed models and programs.

These conditions do not exist in the segment of the GMI studied. While I found their discussions of use in identifying those characteristics of the real problem that make such theories difficult to apply, integration of their models into the GMI scheduling problem did not appear justified.

Chryssolouris, Wright, Pierce and Cobb,(1987) studied Manufacturing Systems Operation in general and Dispatch Rules Versus Intelligent Control at the Laboratory for Manufacturing and Productivity, M.I.T., Boston. Using a variety of simulated situations, they concluded that treating the assignment of production resources to production tasks by heuristic processes employing multi-criteria decision making techniques is equal to or better than using historical dispatch rules. In considering the status of optional scheduling techniques they determined:

1. the use of analytical scheduling methods is ideal, however, their development is extremely difficult and time consuming,
2. simulation techniques are of most value in the testing of physical plant design and control strategies, and,
3. mathematical programming formulations are somewhat inflexible and require impractical computer execution

times.

In short these scheduling options have not been adequate to perform the scheduling tasks in most industries. While this work suggests a future direction, it is another example of laboratory research that has not achieved practical success.

In the 1987 Conference on Advances in Production Management Systems edited by A.Kusiak(1987), 57 papers were presented. The majority of works were theoretical models. The few that described practical system solutions discussed MRP systems in non garment industry situations.

In the Fourth International Conference on Expert Systems in Production and Operations Management(1990), approximately 40 of over 60 presentations discussed scheduling related research. According to a panel led by John Kanet(1990) only five industrial working expert scheduling systems existed at that time. While his estimate likely did not include the system described in Case III of this thesis and I did not see the background research for his statement, the credibility of the panel could not be denied. The results of this conference serve to emphasize the popularity of research into expert systems for scheduling, and the need for practical research such as carried out in this study.

In the garment industry, although MRP systems have been implemented successfully since the advent of the mini computer, few have addressed the scheduling task specifically(Peterson 1984, 1985, 1986, 1987, 1988, 1989, Peterson & Weigelt 1990).

In a survey of 50 garment industry companies in North

America, over 90% indicated a need for a better scheduling systems(Owen 1988, 1991).

In a review of Decision Support Systems authors, many applications and categories of DSS's are described. However, scheduling DSS's are not identified(Alter 1980, Stabell 1983, Bennett 1983, Carlson 1983)

In the field of expert systems as applied to scheduling, Fox(1986) has conducted extensive research but has yet to identify more than one industrial application. Steffen(1986) surveyed the status of expert scheduling systems publications and determined that only three working industrial systems had been reported. In "The Rise of the Expert Company" by Feigenbaum, McCorduck and Nil (1988), Paul Harmon catalogued 139 ES applications. None of these were expert scheduling systems for manufacturing.

Based on the justification of the need in the garment industry, which is not satisfied by existing systems, and little evidence that either DSS or ES systems have provided adequate solutions to the scheduling problem, there is a strong suggestion that this field requires further research, development and illumination.

This study is important to the illumination of this field because:

1. The study was conducted over a 7 year period during which considerable detailed research and development was completed.
2. The data compiled from three actual cases is rich and highly relevant to this emerging field of expert scheduling systems.
3. The cases achieved varying degrees of clearly

identifiable success that can be reasonably related to identifiable variables or causes.

4. The GMI has a recognized need for better scheduling systems, and this work is unique and original in this domain.

1.4. STUDY HYPOTHESIS HIERARCHY

In my research into the theory of knowledge and its advancement I have found the fundamental scientific research model embodying purpose, problem and hypothesis testing, as described by Hillway(1964) and Dawe(1978), was most helpful in organizing and presenting this research.

At the risk of overuse, but at the gain of clarity, the context of this study can be represented concisely as a set of hypotheses, organized into a hierarchy that was initiated in 1984, and has evolved to its current level.

The specific hypotheses that form the background and scope of this study are listed below and are organized into the hierarchy illustrated in Figure 1.1.

Hypotheses Descriptions:

H1: Corporate profits will improve if late deliveries are reduced.

> H1: was implied by the Case I Chairman's opening remarks; "So you think you can solve our scheduling problems ?",
>
> The scheduling problems were primarily late customer deliveries

H2: Better scheduling methods will reduce late deliveries.

H2: exists by definition of the scheduling task.

H3: Better scheduling methods will result from using automation.

H3: was implied by the Chairman's request for my assistance based on my systems background,

H4.1: The use of Word processing/text editor technologies results in successful GMI scheduling systems. (Discussed in Case I)

H4.1: was attempted by the scheduler who proceeded my involvement in Case I. Late Delivery problems were not solved and the scheduler was reassigned prior to his eventual departure.

H4.2: Existing garment industry MRP packages address sufficient needs of scheduling to achieve a significant/acceptable performance level.(Was not valid-Peterson 1984-1990)

H4.2: was my first attempt to find a scheduling solution. It was unsuccessful.

H4.3: Alternate Information technologies can result in successful GMI scheduling systems.

H4.3: was my next direction after H4.2: failed.

H5: The use of DSS technologies results in successful GMI scheduling systems. (Studied in Cases)

H5: was the foundation of Case I and is reported in Chapter 5, and for Case II, in Chapter 6.

H6: The use of Expert Systems Technologies results in successful GMI scheduling systems. (Studied in Literature review and Case III)

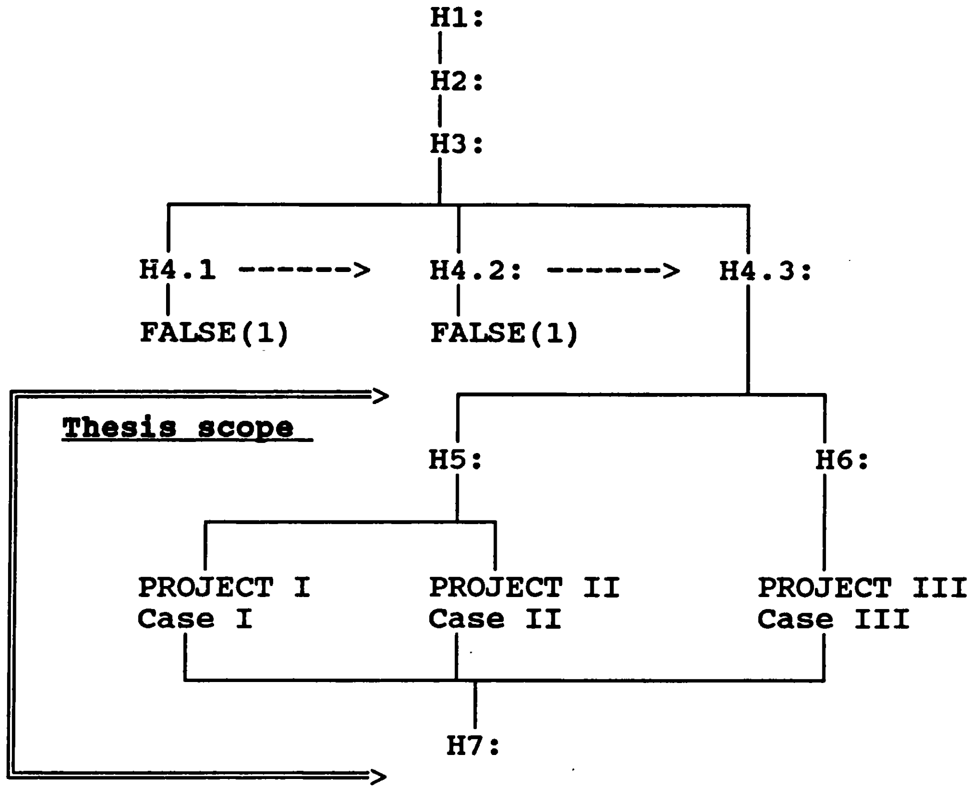
H6: was the foundation for initiating Case III, described in Chapter 7.

H7: The merging of DSS and ES technologies results in successful(useful and usable) Garment Industry Scheduling Systems. (Main Hypothesis of this study)

H7: resulted form the initial discussions between Dr. R. Green and myself regarding the relationship between ES and DSS systems.

The detailed analysis of the hypotheses of this study and the methodology of testing their validity is discussed in chapter 2.

Figure 1.1
Hypothesis Hierarchy



(1): These Hypotheses were not true(Peterson(1984)).

1.5. OBJECTIVES, SCOPE AND LIMITATIONS

1.5.1 Study Objectives

The main objectives of this study are:

1. In general, to help the garment industry improve profitability through the use of scheduling systems.
2. To identify those concepts from the fields of both DSS and ES which, when merged suggest a promising solution strategy for the design of future scheduling systems.

Secondary objectives are:

3. To provide company and production management with a clear statement of the importance of various organizational processes and policies on the success of a scheduling system.
4. To provide system developers with a set of guidelines for designing future scheduling systems.
5. To compare the results of these cases with the conventional wisdom of related fields.
6. To propose an architecture for the design of future expert scheduling systems.
7. To advance the knowledge of participative research as an accepted methodology for management research.
8. To propose research questions for continuation of related research.

1.5.2. Scope

The scope of this study considers scheduling systems in the following context:

1. Industrial scope:

Within the garment manufacturing industry, there are many companies that produce items that are of a **seasonal and fashion nature.** eg: ladies sportswear. Within this category, many produce goods based on "bookings" or orders received for future delivery. This is the traditional "make-to-order" production environment(Kurt Salmon Associates 1988, Gaetan 1989).

2. Internal Company scope:
Such "make-to-order" companies are faced with the tasks of scheduling raw materials and capacity to achieve completion of production for predefined customer order delivery dates. Failure to deliver by cancellation date results in lost sales and reduced customer loyalty.(Wild 1985)

3. Scheduling Activity Scope:
The major activities involved within the scheduling function are considered, with emphasis on the role of the scheduling systems.

4. Organizational Transition:
In the three cases presented, the transitions are viewed firstly; from the design process, including the identification of the need, the initiation of the scheduling system project, the development of the systems,
secondly; from the design of the systems, and
thirdly; from the operation of the systems after full system implementation.

5. System Technologies:
The types of systems studied fall within the general field of Information Technology and are known as Decision Support Systems(DSS) and Expert Systems(ES).

Expert Systems fall within the general field known as Artificial Intelligence(AI), and are closely related to Knowledge Based Systems, Intelligent Systems, Smart Systems and other systems replicating human intelligence.(Harmon & King 1985)

6. Study Viewpoints:

The study considers the following elements of the scheduling functions and systems:

A. The Process of Design:

   a. The Organizational Environment including Management policies, actions, and Production and Operations staff,
   b. DSS and ES System design methodologies
   c. PC based technologies.
   d. Proving the system works,
   e. Post Implementation review.

B. The Design Representations:

   a. DSS and ES Model concepts
   b. Modelling of the production facilities,
   c. Modelling of the material acquisition process,
   d. Modelling of a schedulers knowledge,
   e. Integration of the models into a scheduling system,
   f. Creation of a scheduler's workstation,

C. The Determination of Scheduling Systems Success or Failure.

7. Participative Research:

   1. Multiple Roles of the researcher
   2. Strengths and Weaknesses

1.5.3. Study Limitations

Apart from my own dissatisfaction at not being able to be more precise, more concise and yet completely encircle the topic of choice, I am also deeply aware of my bias in viewing and reporting on these cases, the literature and the results.

The challenge of encircling this topic, while retaining a standard format and prescribed length resulted in my study of research methods. In theory I should have been able to define an hypothesis that had no opportunity for open questions. In reality, this may not be a realistic expectation, given the case study format. In my attempt to be thorough I have probably been tedious in some descriptions while curt in others.

While the case study methodology is powerful, flexible, and widely applicable, I have also found it difficult to control and thus I have attempted to define my own structure. I believe that only after many such studies would I begin to feel comfortable and confident that my structuring was appropriate.

Nonetheless, I believe the case study approach is appropriate for this early study into this new field. The newness of the field is another limitation of this research. In the evolution of a particular field of knowledge such as DSS, sufficient practice eventually develops that surveys such as Bennett(1983) can be conducted and broad conclusions safely formulated. In a new field such as expert scheduling systems there have been so few working , practical applications that studies such as this one may be proven to be irrelevant as the field develops further.(Steffen 1986)

As an early exploratory study this research draws it strength and value from the three industry cases, of sufficient duration and depth to suggest important results.

A major limitation in the study of any scheduling related field is the need to be selective on the breadth of past scheduling literature reported upon. Although my literature study included scheduling theories and techniques in the fields of Operations Research, Simulation, Production/Operations Management, MRP, and many of the subfields addressing scheduling within these broad areas, I could not do justice to these so I had to omit their detailed consideration. The test of relevance to the hypothesis testing became my final filter for determining what to report in this thesis. Applying this same filter has resulted in the elimination of discussions on Decision Analysis and Japanese manufacturing techniques.

I look forward to future studies that will offer the opportunity to return to these interesting fields.

In summary, in the emerging field of Expert Scheduling Systems, this research is one of the early explorations. Although the results are promising, considerably more research and practice is required to advance the technology into maturity.

1.6. RESEARCH QUESTIONS

Although I found the use of the Hypothesis description the most useful discovery of my research into research, I recognize that the restatement of the general focus of the study into research questions can provide further enlightenment.

This research attempts to answer the following questions:

1. Does the merging of elements of DSS and ES technologies result in more successful scheduling systems than either technology by itself. Which elements of each technology can and should be merged to produce the advancement?
2. Can the scheduling function be automated to the benefit of garment manufacturers ?
3. Can DSS technologies be successfully applied to scheduling systems ?
4. What are the limitations of DSS technology applied to scheduling problems ?
5. Can the expert systems paradigm be applied to garment industry scheduling systems ?
6. How important are the scheduler's tools in the scheduling function ?
7. Can a consultant become a researcher ?
8. Can participative research work in this environment ?

1.7 SUMMARY OF THE DISSERTATION

The presentation of the thesis is organized accordingly:

PART I: INTRODUCTION

CHAPTER 1 - INTRODUCTION introduces the study and defines what the research proposes to accomplish and how it is organized.

CHAPTER 2 - METHODOLOGY describes the organization of the research, the sequence of cases and events, the role of the researcher and the methods of data collection and some limitations of this approach.

CHAPTER 3 - THE FASHION CYCLE AND THE SCHEDULING FUNCTION describes specific characteristics of the garment industry from the traditional Productions/Operations Management perspective, and in particular, the companies studied in this thesis, and how these companies create scheduling problems.

CHAPTER 4 - CONVENTIONAL WISDOM discusses the literature in the areas of:

	DESIGNING METHODOLOGIES	DESIGN REPRESENTATIONS
Decision Support Systems(DSS)	Alter(1980) Bennet(1983) Martin (1984)...	Stabell(1983) Carlson (1983)...
Expert Systems(ES)	Harmon & King (1985) Feigenbaum(1988)...	Hayes-Roth(1983) Schoen(1987)...
Expert Scheduling Systems(ESS)	Newman(1987), Gaines(1987)... Borne & Fox (1984).	Fox(1983, 1986) Nassr(1985)

From this literature study a framework for the categorization and comparison of the three cases is formulated.

PART II: THE CASES present the field work and data collected for each of the three cases. Chapters 5, 6 and 7 discuss Cases I,II and III. The setting of each case is presented, followed by a discussion of the development project. Finally, the results of each project are presented.

PART III: ANALYSIS, summarizes and aggregates the findings from the cases and compares the findings with the body of relevant literature, in Chapter 8. The detailed Guidelines for the Development of Scheduling Systems(Appendix E) presents the lessons of this study for future consideration by management and developers in the garment industry.

PART IV: CONCLUSIONS discusses A GENERAL ARCHITECTURE FOR SCHEDULING SYSTEMS the synthesis of the cases and the literature for a future developer.(Chapter 9)

Chapter 10: CONCLUSIONS AND FUTURE DIRECTIONS attempts to realistically assess the contributions of this work and proposes possible further related research.

CHAPTER 2 - METHODOLOGY

2.1. EVOLVING A METHODOLOGY

One of the most difficult aspects of this research has been the definition of the methodology. While the early beginnings of the research were clearly focused on Scheduling in the Garment Manufacturing Industry(GMI), Decision Support Systems(DSS), Expert Systems(ES), and the detailed study of the application of DSS, ES to the GMI scheduling problem, it has taken me several years of searching to return to the original purpose.

Upon reflection I see that I have been on an exploration for a solution or a method of solution. Because there was very little research in the area defined by the union of the GMI, Scheduling, DSS, and ES fields, I had to explore each field separately before I could return to my central purpose. Specifically, the fields that I examined and their context, included:

A. Garment Manufacturing Industry
   1. Six Companies in this industry.
   2. Several GMI-MRP systems.
   3. Attendance at 5 International GMI Exhibitions,
   4. Japanese Manufacturing Techniques

B. Traditional Scheduling Fields of Research
   1. Production/Operations Management(P/OM) literature.
   2. Operations Research(OR) and Simulation literature.
   3. Decision Analysis(DA) literature.
   4. Mathematical Theory of Production Planning

C. Information Technology
   1. Macro Success Factors
   2. Micro Success Factors
   3. Decision Support Systems(DSS)

4. Expert Systems(ES)

D. Manufacturing Systems

1. Modern Production Management Systems Literature

2. Expert Systems Applications in Production

F. Detailed GMI Scheduling Case Studies

1. Case I: a 36 month study of the development of a scheduling DSS.

2. Case II: an 11 month study of a scheduling DSS.

3. Case III:a 36 month study of the application of ES to scheduling.

Was the study of each of these areas necessary? I would argue yes, since each area did have some relevance to the original problem and purpose. At the same time I concede that some areas were less relevant then others; namely, Decision Analysis(DA), and Japanese Manufacturing Methods(JMM). However in the study of DA, I came to a new appreciation of the definition of Performance Measures, and techniques of Multi-Criteria Decision Making. In the study of the Japanese methods, I answered the question of why the Just-In-Time(JIT) method is not suited for the seasonal-fashion segment of the GMI; because the requirement for continual production of very similar products does not exist.

The most difficult fields for me to address in this study were those of traditional scheduling research,i.e. OR, Simulation and Production Operations Management(P/OM). The OR literature is extensive and complex. The many works describing years of attempts at formulating optimal mathematical solutions, illustrate the magnitude of the complexity of this combinatorial optimization problem. In the end, I have had to make the difficult decision to remove a previously written chapter on OR because it offered no solution to my problem.

Similarly, in the field of simulation, I have laboured with the appropriate means of including the record of my search and the importance of this topic to me. Having worked in this field for many years(Peterson 1968, 1971), I am well aware of the strengths and limitations of applying simulation to industrial problems. The model building concepts of simulation have long been recognized for their educational value to the model builders(Bobillier 1976). The analysis of control rules is still a very current use of simulation(Chryssolouris 1987). In the development of the solutions described in the three cases the "what-if..", capability pioneered in the field of simulation, has been incorporated initially through spreadsheet based systems, then in a graphical model. I have also found that in many of the works in Modern Production Management Systems research, the basic concepts of simulation are pervasive. Thus, although I have not specifically written a chapter on simulation, this field is represented throughout the study.

In the final analysis I selected the field of P/OM as the framework for the description of the GMI Scheduling problem, and for the comparison of the scheduling models employed in each of the cases.

In the process of researching research, I found most help from works by Hillway(1964) and Dawe(1978). My initial problem of focusing the research to a manageable size and problem became evident over many weeks of contemplation on the theory of how knowledge is advanced in our world.

Although I had attempted to follow the models of past Bath scholars(Sims 1978, Armstrong 1979, Brewer 1981, Cumberlidge 1982, Diggory 1983, and Pye 1984), it was not until I was reacquainted with the "Scientific Method" and the model of basic scientific research that I was able to see a structure for the methodology and presentation of this study. Hillway's(1964) analogies of the relentless detective searching for relevant clues and an experienced prosecutor critically studying evidence were meaningful to my emerging appreciation of scholarship. I have come to appreciate Hillway's(1964) statement: "research requires thought". I have spent many hours in deep thought considering the meaning of scientific thinking, critical thinking, reflective thinking, reasoning from evidence, types of evidence, cause and effect, inductive reasoning and deductive reasoning. As Harrison(1984) reflected in his dissertation, I have thought about what to think about.

I was able to see an emerging structure that paralleled the traditional research models of:

- Research Area
- Purpose of research or problem to be solved
- Hypothesis
- Testing the Hypothesis
  - Methodology, how to test the Hypothesis
  - Collection of relevant, material and qualified data
  - Data Analysis and Observations
- Formulating Conclusions
- Statements of Theory(Hillway 1964)

In this context I was able to define the following:

<u>Research Area:</u> GMI Scheduling Systems

<u>Purpose:</u>

To study the role of Decision Support Systems and Expert Systems in designing and the design of garment manufacturing industry(GMI) scheduling systems.

<u>Hypothesis:</u>

The merging of DSS and ES technologies results in successful(useful and usable) Garment Industry Scheduling Systems.

<u>An Ideal Methodology:</u>

If a perfect research laboratory existed, one possible methodology might be to;

1. Evaluate DSS GMI Scheduling system cases.
2. Evaluate ES GMI Scheduling system cases.
3. Evaluate DSS/ES GMI Scheduling system cases.
4. Compare Results of DSS, ES, and DSS/ES cases.
5. Formulate Conclusions.

<u>Study Materials Available for Data Collection:</u>

Without such a perfect laboratory I could only work with the data available, namely:

1. Literature in the fields of: Production/Operations Management, OR, Simulation, Manufacturing Systems, Decision Support Systems, and Expert Systems.
2. Literature and experience in the garment manufacturing industry.
3. Three case studies involving the designing and design of garment industry scheduling systems.

<u>Methodology Used:</u>

Thus I determined that my methodology would be:

1. Detailed review of the literature in the relevant areas.
2. Formulation of case study comparison characteristics from the literature into a Case Description Outline(CDO).
3. Analysis of the three cases according to the defined CDO.
4. Comparison of the literature findings with the case study findings.
5. Analysis of the results of the comparisons, and testing of the hypothesis validity in each case.
6. Formulation of conclusions and expansion of these conclusions to formulate new theories and concepts.

Observations:

As described in Chapters 4,5,6,and 7.

Conclusions:

As described in Chapters 8, 9, and 10.

2.2 HYPOTHESIS METHODOLOGY

Dawe(1978) prescribes an approach to research of carefully defining the hypothesis and then planning a methodology to test the hypothesis. in essence, once the hypothesis testing is planned the remainder of the study is straightforward.

In considering the main hypothesis of this study:

The merging of DSS and ES technologies results in successful(useful and usable) Garment Industry Scheduling Systems;

it is necessary to consider the dual nature of the two technologies of DSS and ES. One issue is how to consider the effect of either DSS or ES technologies on the eventual success. I reasoned that to prove the main hypothesis I had to know if success could be attributed alone to either DSS or ES technologies. Thus I formulated the supporting hypotheses of:

H5: The use of DSS technologies results in successful GMI scheduling systems.

H6: The use of Expert Systems Technologies results in successful GMI scheduling systems.

If H5: and H6: were true then I would have a strong, although not perfect, argument for proving H7:. On the other hand if either H5: or H6: were not true, I would still have to locate alternate proof of H7:

From the viewpoint of availability of data, I had Cases I and II to test H5: and Case III and related study to test H6:. The literature in the union of these areas was scarce, so I had to rely on the Cases, primarily.

The testing of H5: and H6: was planned accordingly:

Each of the hypotheses H5:, H6:, and H7: require the identification of an example of a technology and the successful application of that technology.

In reference to the two technologies of DSS and ES, I deduced from my study of both fields that these technologies were defined by the following:

1. A Paradigm or basic concept of what it is, and how it works,
2. A methodology of application
3. Characteristic representations or manifestations of the technology

4. Examples of each in use.

Thus the study of these technologies becomes a study of the paradigm, the methodology or design process, and the resultant design representations.

The determination of "Successful Systems" was aided by consideration of the literature in the Information Technology field. Several authors have proposed various measures of system success(Montazemi(1986), Raymond(1985). From my analysis of these measures the concepts of "used", meaning user acceptance, and "useful" meaning "of value", resulted.

I then turned my attention to the analysis of the cases in a relevant, concise manner that would facilitate the easy testing of the Hypotheses, H5: and H6:. From studying the Information Technology literature, and with guidance from Hillway(1964), I determined that a type of questionnaire to determine the classification of a system as DSS or ES, and to measure the success elements, when applied to the three cases, would be a consistent and efficient means of identification for purposes of the Hypothesis testing. I called the resulting instrument the Case Description Outline(CDO). The CDO is defined in Chapter 4, and illustrated in Appendix A1.

In this manner, I follow Dawe's(1978) emphasis on Hypothesis testing as a basis of the study's methodology.

2.2.1 Hypothesis Testing

The testing of H5:for the DSS technologies and H6: for the ES area were planned as follows:

------- DSS ------

H5:

DSS Hypothesis: The use of DSS technologies results in successful GMI scheduling systems.

H5:Test

1. Study the application of DSS to scheduling.
2. Evaluate Results against "Successful Performance criteria".

Study Design:

1. Define DSS technologies.
2. Conduct/study DSS Scheduling Project(s).
3. Observe the use of DSS concepts and corresponding results.
4. Formulate Conclusions.

Study Method:

1. Definition of DSS technologies:

   DSS Technologies consist of:

   A. DSS Paradigm

   B. Designing methodologies

   C. Design concepts

   D. Evaluation/Performance Criteria

   Expanding B,C and D results in:

   B. Designing
   1. Methodology
      1. Focus on Decision
      2. Players
      3. Processes
      4. Model Building
      5. System Building

   C. Design
   1. Model Representation
      1. Sched.Entities
      2. Interaction
   2. System Representat'n
      1. Information
      2. Tools
      3. User Operation

D. Evaluation/Performance Criteria Definition.

2. Conduct/Study DSS Scheduling Projects:

   1. Case I. Designing, Design, Evaluation

   2. Case II. Designing, Design, Evaluation

3. Observations of DSS Designing, Designs and Results.

4. Formulate DSS conclusions.

------- ES ------

H6: ES Hypothesis: The use of ES technologies results in successful GMI scheduling systems.

H6:Test
1. Study the application of ES to scheduling.
2. Evaluate Results against "Successful Performance criteria".

Study Design:

1. Define ES technologies.
2. Conduct/study ES Scheduling Project(s).
3. Observe the use of ES concepts and corresponding results.
4. Formulate Conclusions.

Study Method:

1. Definition of ES technologies:

   ES Technologies consist of: Paradigm as represented in:

   A. ES Paradigm

   B. Designing methodologies

   C. Design concepts

   D. Evaluation/Performance Criteria

In detail B, and C were studied accordingly:

B Designing	C. Design
1. Methodology	1. Model Representation

1.Focus on Expertise/KB 1.Sched.Representn

2.Experts/Know.Eng'rs 2. Rules

3.Heuristic/Rules 2. System Representation

4.Model Building 1.Inference Engine

5.System Building 2.Explanations

3.User Operation

C. Evaluation/Performance Criteria Definition.

2. Conduct/Study ES Scheduling Projects:

   1. Case III. Designing, Design, Evaluation

3. Observations of ES Designing, Designs and Results.

4. Formulate ES conclusions.

The testing of H7:, the merging of DSS and ES technologies, focused on Case III as an example of the merging of these technologies in an attempt to confirm H7:.

2.3. ORGANIZATION OF THE LITERATURE AND CASES

Within the DSS and the ES fields the technologies can be analyzed from many viewpoints. Many authors discuss DSS and ES cases from the viewpoints of The Design Methodology and the Design Representations.(Alter 1980, Bennett 1983, Stabell 1983, Turban and Wilkens 1986, Harmon and King 1985).

Considering the Design methodologies and the Design representations the study can be represented by the following table.

STUDY ORGANIZATION

	DESIGNING METHODOLOGIES	DESIGN REPRESENTATIONS
Decision Support Systems(DSS)	literature, Cases I,II,III conclusions	literature, Cases I,II,III conclusions
Expert Systems(ES)	literature, Case III	literature, Case III
Expert Scheduling Systems(ESS)	literature, Case III, conclusions	literature, Case III, conclusions
Future Scheduling Systems	Guidelines	Architecture

2.4. METHODS OF DATA COLLECTION

The sources of data for this study were:

1. Relevant literature in the fields of: Production/Operations Management, OR, Simulation, Manufacturing Systems, Decision Support Systems, and Expert Systems, including Expert Scheduling

Systems.

2. Relevant literature and experience in the garment manufacturing industry.
3. Three case studies involving the designing and design of garment industry scheduling systems.

The methods of data collection consisted of:

1. Analysis of many of the popular authors in the fields related to this research, namely:
   1. The Production Scheduling Function,
   2. The Garment Manufacturing Industry,
   3. Computer Based Information Systems, in general, and
   4. Decision Support Systems, and
   5. Expert Systems, specifically.
2. Synthesis of the literature into a Case Description Outline(CDO) for the analysis of the three cases(Appendix A1). The literature in the field of DSS is extensive with several studies of actual cases. The evidence describing the methodologies and designs of successful DSS applications is substantial. In the emerging field of ES, early successes have been studied, and a theory of design methodology is developing. This methodology, and their variations cannot be viewed with the credence of the DSS methodology.
3. Accumulation of detailed documents describing the work involved in each of the three cases. These documents included samples of computer outputs, management and committee meeting reports and

memoranda describing many aspects of the cases, copious notes recorded by me in my roles as a participant in each case, and time sheets detailing the activities performed by a variety of staff in their work related to the cases.

4. From the case material collected, various Chronological charts of the major activities and events were prepared to organize the remaining case material.
5. From the recreated sequence of activities, events and documents the Case Description Outlines(CDO) were completed describing the characteristics of each case.
6. The cases were summarized and presented in chapters 5,6, and 7, with the COD's in Appendices B1, B2, and B3.
7. In each case the hypotheses were tested and the resulting discussion presented in the chapter.
8. The results of each case were then combined and relevant conclusions discussed.
9. The conclusions were then extended to define detailed design methodology and representational guidelines for future ESS systems.
10. Finally, the results of this study and the theories of other researchers were used as a base for the synthesis of an Expert Scheduling System Architecture.

2.5. CASE STUDY APPROACH

2.5.1. Summary of Cases

The case study methodology at the University of Bath is strong (Armstrong 1979, Sims 1978, Brewer 1981, Cumberlidge 1982, Diggory 1983, and Pye 1984). From these excellent examples and the guidance of Bennett (1986), the case study methodology was identified as most appropriate. The three cases studied occurred in the period 1984 to 1990 as indicated below:

	1984	1985	1986	1987	1988	1989	1990
Case I	**	****	****	**			
Case II					**	**	
Case III				**	****	****	****

CASE I:

Although the three cases are interrelated, this thesis began as the study of Case I. In Bennett's(1986) terms, as the researcher, I was in the midst of an "intensive examination of a single unit" and specifically pursuing an "exploratory study" seeking to establish what is; and to discover the significant variables and relations between them. As an exploratory study, I was interested in the scheduling problem from a management and operational level and how the development of a scheduling solution using Decision Support Systems technology evolved. This evolution from 1983 until 1987 was traced and is described in Chapter 5 of this thesis. In addition to the exploration for better understanding of the scheduling function and the evolution of an interim scheduling system in the first Canadian company, my search for more knowledge into this field led me to visit three companies in Europe; Alexandra in Bristol, U.K., and Pola Paita and Verke in Finland.

CASES II and III

The study of Cases II and III followed Case I, in the period from 1987 to 1991. Initially, the thesis was to be about Case I, and the detailed study of the evolution of the Scheduling System in that company. Since 1984 when the study began, my understanding of the fields of DSS and ES has increased, and, with the assistance of Dr. R. Green, and the advice of my viva committee, the decision was made to enrich the research with Cases II and III. The addition of these two cases has enhanced the original thesis significantly.

2.5.2. Case Study Background

The research into Case Study Methodology led me to a specific work by Bennett(1986). Several characteristics of case study research cited are relevant to my experience. These are:

Flexible Structure:

In attempting to describe the methodology and the flow of this research I was encouraged by Bennett's (1986) comment that:

"A key point to note about such studies (case studies) is that they do not attempt rigorous control. This is both a strength and a weakness."

and further:

"While the intensive investigation of a single manager or group of people or organizations may be carried out for the sole purpose of increasing our knowledge of management, more often than not is carried out in order to make practicable improvements. Any contributions to general knowledge are, therefore, incidental. A case study approach may, therefore, have research, consultancy, and management training objectives attached to it."

Such was the situation in Case III.

Presentation Format:

Bennett(1986) prescribes, firstly, the "prior situation" is described. Subsequently, as the evolving situations are described, various observations are made which result in the formulation of conclusions.

Cause and Effect: Dependent and Independent Variables:

A major portion of this research falls into Bennett's(1986) category of model building. He identifies:

"An important part of the research process is the building of models to represent cause, effect and other relationships. . . . They may also be the end product of research, with little by way of a conceptual framework having been in existence at the start." (pp. 29)

Although three Cases are not sufficient to establish general conclusions, they do provide a unique opportunity to study three situations where many of the independent variables are very similar. From a research viewpoint, this is desirable since it facilitates the identification of those variables or factors that have the most significance in determining the dependent variable. In broad terms the dependent variable in this study was the value or performance of the scheduling systems to the companies.

Is this accepted research methodology? Bennett suggests that it is: "Whilst for many purposes a single method may be appropriate, the possibility and advantages of combining different methods should be considered." (pp. 40)

Enhancement of Personal Knowledge: Research Beginning:

This research was initiated by the belief that somewhere in the vast literature related to decision support systems and information technology, production/operations management, operations research, and other related fields such as decision analysis and Japanese manufacturing techniques, there must exist a solution which could be realistically implemented in organizations of the types studied in Case I. Thus the original study began as a search for personal knowledge that could be applied to help the GMI. This search began as a literature search and as a practical search for solutions in other GMI companies.

At the same time as these fields of literature were being reviewed, the emergence of the expert systems methodologies and techniques could not be avoided. What began as a search for a "package solution"; one existing in a nice convenient form of implementation, gradually, but with increasing momentum, became a process of model building utilizing the general framework of the field of production/operations management set in a conceptual system based on expert systems technology and methodology.

Reviewing existing expert systems wisdom was difficult because the field was so young. While a few studies were found that describes the existing base, the vast majority of the literature is of the case study variety where emerging theories have yet to be proven. Through the process of synthesis, the many concepts, techniques, and methodologies reviewed and studied as part of this research began to emerge into an expert system to perform the scheduling function.

Along this figurative journey; searching for the scheduling system solution, the literature review and case study analysis led me to detailed reflection on the process of decision making and problem solving and its relationship to expertise. Works by Sims (1978) and Cumberlidge (1982) were helpful in this reflection. I believe these reflections and the synthesis of them with expert systems technology will provide fruitful grounds for future research.

Participative Research

The study described in this thesis, while being structurally described as a case study followed by a model building process, must also be viewed as an example of participative, action research. As Brewer (1981) described in his transformation from an employee to a researcher, I also discovered a transformation from a consultant to a researcher. To those who have made this transformation before, the viewpoint of developing a "critical eye" may have resulted. While, in part, I believe this has occurred with me, in truth, the development of an intense curiosity for why things are as they are, and the manifestations of cause and effect within organizational functions, methods, policies, procedures and objectives, would more accurately identify my transformation.

Coupled with this development of an intense curiosity has been the melding of discipline and perseverance to pursue literary works, others' research, and the related mental exercises that attempt to develop the thoughts from previous research beyond those concluded from that research. Often this form of reflection and curiosity became its own reward as many tangents were pursued that, although of no significance to this research, still excite me when I think of them as future research projects. From the viewpoint of a critical eye in viewing past research, I spent considerable time on such pursuits, independent of this study.

As a general conclusion from this research, Bennett(1986) again understands when he states: "The results of research can contribute to the development or enhancement of personal knowledge, in both general and specific ways."

followed by:

"Research is, in itself, an important process of self-development for all those who become involved in it - researcher and manager."

In any case, I have been both and have found it a true experience of self-development.

2.6. CASE STUDY OUTLINE

The choice of specific characteristics to study in each case is vast. From a consideration of hundreds of case descriptors that previous researchers have used, an outline has been defined to identify the relevant dependent and independent variables.

From a research perspective the independent variables were:

1. The Company Environment(The Setting), prior to and during each project, as suggested by several authors.(Gibson and Nolan 1974, Huff and Munro 1985, King and Kraemer 1984, Ein-Dor and Segev 1978).
2. The Design Process, as defined by the project methodologies.(Alter 1980, Montazemi 1986, Bailey and Pearson 1983, Raymond 1985).
3. The Design Representation, as embodied in the resulting systems.(Alter 1980, Montazemi 1986, Bailey and Pearson 1983), Raymond 1985, Martin 1984).

The dependent variables studied in this research is:

1. The Performance of the resulting systems in the form of success indicators suggested by Montazemi(1986), Bennet(1983), Martin(1984), Lucas(1975), Clowes(1979), and Vose (1990).

These variables have been expanded into the outline defined in Figure 2.1.

Figure 2.1
Case Description Outline

The Setting:

1. Organizational situation.
    1. Co. strength
    2. Management strength
        1. Organization
        2. Formal Strategic Planning, Control and Review.
        3. Tactical Planning, execution and control systems.
        4. Operational plans & control systems.
    3. Manufacturing strength
        1. Organization
        2. Scheduling function
2. Identification of the need.
    1. Need identified by whom and how?
    2. Severity/importance of the need.
3. Initiation of the Project.
    1. Initiated by whom and how?

The Design Process:

1. Project Organization and Goals
2. Project Staffing
3. Project Methodology
4. System Implementation

The Design

1. Scheduling Model
2. Systems Model
3. User Interface and interaction
4. Systems Integration

The Results:

1. Status Indicators
    1. Transition Period
    2. Time to Full and Exclusive Use
    3. Status at 6 month intervals.
2. Performance Indicators
    1. Degree of Use
    2. Reliance on System
        1. Believers
        2. Non-Believers
    3. Accuracy of System
        1. Problem Predictive ability
        2. Solution Analysis ability
        3. Solution Choice ability
3. Value Indicators
    1. Customer order delivery improvements
    2. Management planning/control improvements
    3. Catalyst for other improvements.
    4. External Recognition.
4. Enhancement/Evolution
    1. Strategic
    2. Tactical
    3. Operational
5. Limitations Associated with the System.
    1. Organizational Problems
    2. Technological Limitations
    3. Functional Limitations

CHAPTER 3. THE FASHION CYCLE AND THE SCHEDULING PROBLEM

3.1. INTRODUCTION

The dynamic and exciting world of fashion shows, designers and the latest trends is the primary cause of the scheduling problem in the GMI. A company that designs the best "line" or collection of styles for next year's season will sell more units and be more profitable. In this chapter the relationships between the fashion and seasonal nature of the GMI and the scheduling problem are presented.

The chapter discusses the following main topics:

1. Review of the specific GMI segment studied in the research through an analysis of 6 companies.
2. Detailed analysis of the nature of the Seasonal-Fashion companies studied and the identification of the particular characteristics of this segment that create the need for the scheduling function and the specific problems that must be addressed.
3. Re-statement of the GMI scheduling problem in the terminology of the Production/Operations Management field.
4. A brief review of relevant scheduling literature.

3.2. GARMENT INDUSTRY SEGMENTATION

The characteristics that define the scope of the GMI studied in this research are illustrated in Figure 3.1. As a result of these characteristics these manufacturers produce their products on a "Make-to-Order" basis. This is necessary because the fashion content of most styles is directed to a specific season. This also means that the penalty for a late delivery is usually a cancelled order, and since the style is specific to the season, it has no market value next year. This loss can be significant to the success or failure of the enterprise. In the companies studied in this research the scheduling function was given the responsibility for producing the merchandise in sufficient time to achieve customer delivery dates.

Figure 3.1

Characteristics of Companies Studied

1.	Product Fashion Level (high to low):	mid range
2.	Primary customer	
	a. sex:	primarily female
	b. age	30-60
	c. activities:	career, leisure, evening.
3.	Styles:	coats, tailored jackets, skirts, dresses, pants, shirts, blouses
4.	Seasons per year:	Spring(summer), Fall(winter), Holiday(Christmas /New Years)
5.	Selling Method:	Orders taken from samples displayed at Fashion shows and markets
6.	Delivery Lead Time:	2-6 months from Order
7.	Company Operations:	Style Design, Marketing, Materials, Production, Warehousing and Distribution.
8.	No. of Employees:	300 - 1200
9.	No. of Plants:	2 - 10

3.3. COMPANIES STUDIED

In this research six companies were studied from the garment manufacturing industry. These companies are identified in Figure 3.2. Companies 1,2 and 3 were deeply involved in the development of three separate scheduling systems, and are the subject of the three cases presented in Chapters 5,6 and 7.

The other three companies; 4, 5, and 6 were studied to identify representative characteristics of the GMI scheduling activities and problems, and to assist in the definition of the specific segment studied in this research.

The main functions performed within these six companies are:

1. Merchandising, of their own seasonal fashion designs by assembling a line of fashion items into specific "groupings" of garments which they market themselves,
2. Sales and marketing activities including the planning for sales campaigns, the selling and writing of customer orders for their finished garments. In this context, sales agents have been used as a means of selling their product to retail stores.
3. Production of the garments, usually by in-house production facilities either owned, managed and operated, or through close association with contractors of manufacturing facilities.
4. Distribution of the finished garments to meet the demand of accepted customer orders, and
5. Various administrative activities related to the foregoing functions.

These companies typically follow an annual Product cycle like the one illustrated in Figure 3.3.

Figure 3.2
Companies Studied

	---- Companies Studied ---					
	1	2	3	4	5	6
Characteristic:						
Country:						
Canada	Y	Y	Y			
U.K.				Y		
Finland					Y	Y
Fashion Level:						
Medium	Y	Y	Y		Y	Y
Low(Uniforms)				Y		
Seasonality:	Y	Y	Y	N	Y	Y
Production Initiation:						
Make-to-Order	Y	Y	Y		Y	Y
Make-to-Stock				Y		

The specific companies studied were:

Co. #:	1.	2
Name:	Tan Jay	Sterling Stall
Location:	Winnipeg, Canada	Winnipeg, Canada
No.of Employees:	1200	500
No.of Plants:	10	5
Co. #:	2	4
Name:	Freed & Freed	Alexandra
Location:	Winnipeg, Canada	Bristol, U,K,
No.of Employees:	400	400
No.of Plants:	4	2
Co. #:	5	6
Name:	Pola Paita	Verke
Location:	Laprenrunta, Finland	Verke, Finland
No.of Employees:	300	400
No.of Plants:	2	3

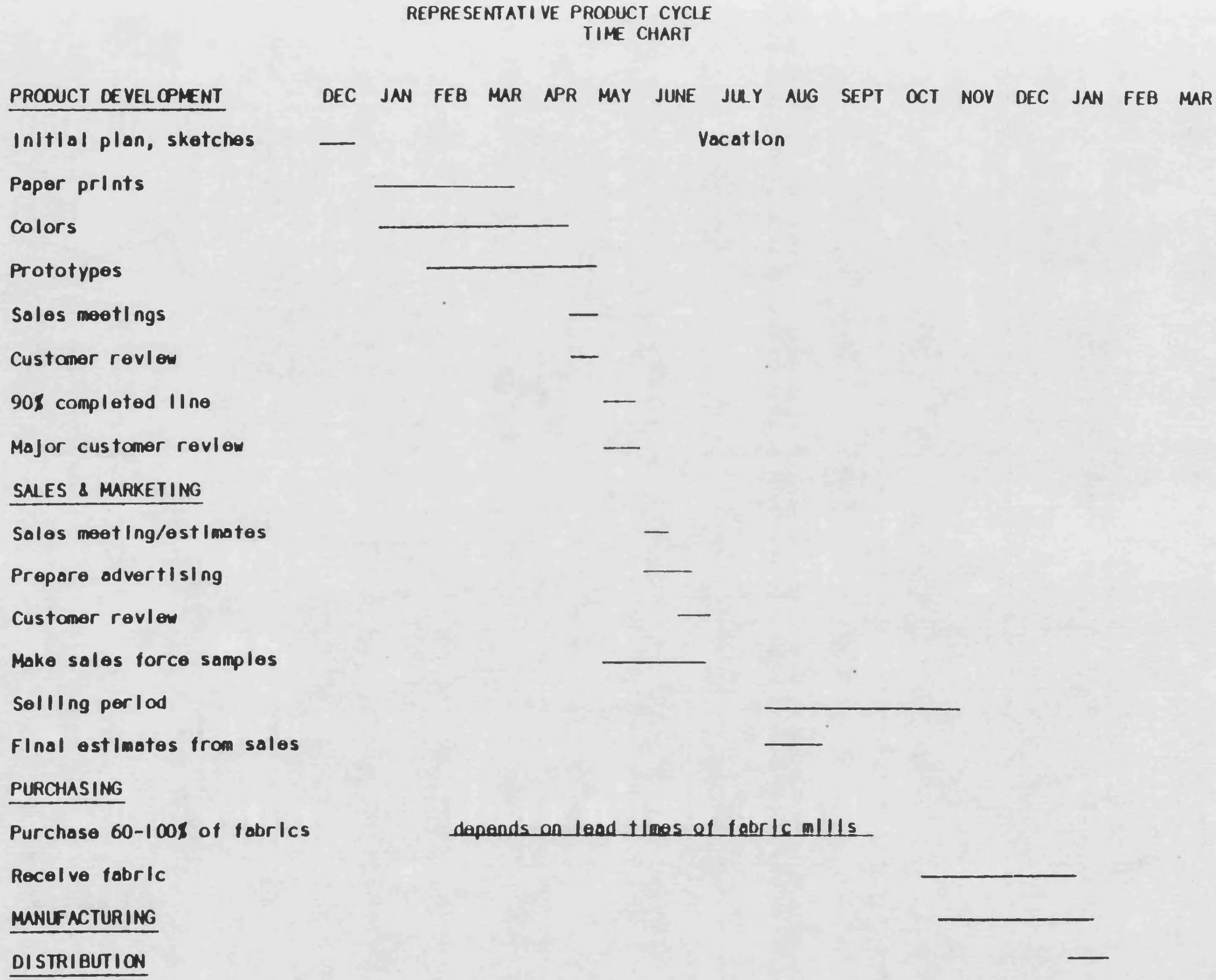


Figure 3.3

ANNUAL PRODUCT CYCLE

3.4. SCHEDULING FACTORS

3.4.1 The Fashion Elements

The three Canadian companies and the two Finnish companies studied in this research are manufacturers of women's casual and career oriented clothing. The company visited in the U.K. is a manufacturer of men's and women's uniforms and general work wear. The companies are involved in the "medium fashion" market segment. In all cases, the markets could be classed as "everyday wear".

Although such businesses are not in the "high fashion" market, the existence of fashion trends is a significant factor on the design and marketing of their products. If a collection to be marketed does not contain sufficient attraction to the market place because of the absence in the collection of the current fashion trends, then the company will not successfully sell such collections to its retail customers. On the other hand, if a collection of models or styles has the right combination of fabrics, colours, and styled features, then the sales of such a collection can easily double the company's own internal forecasts.

Thus, the first significant variable which has an important impact on the production planning and scheduling function is that of the fashion content of the company's collection or line of garments.

The second important factor which has a major impact on the production planning and scheduling function is that of seasonality. Many of the companies of the type studied in this thesis design collections which are specifically targeted to the seasons within the year. In general terms, the seasons are identified by winter wear and summer wear. For some companies, these seasons are further sub-divided to include special holiday and festive garments for Christmas and New Year's, or for winter vacation casual wear often purchased by women living in colder winter climates who enjoy a Mediterranean or Caribbean vacation during the winter. The significance of this seasonality is that if garments are manufactured for a particular season with the corresponding type of styling and fashion features, then, if the sale of these garments is not successful in the appropriate season, their value in the market place drops considerably and often such garments cannot be resold as the fashion trends in the next year have dated those garments left over from the previous year's season. To minimize the occurrence of this problem, companies in this segment of the market place seldom manufacture large quantities of any one garment without customer orders equivalent to the number of units manufactured. In this respect, most companies operate on a "make-to-order" strategy.

The third factor which is a result of the first two that has a major impact on the planning and scheduling function is that of the purchase of raw materials, primarily fabrics, in quantities which are approximately equal to the corresponding number of units ordered in customer orders. A difficulty arises in that often the time required to manufacture and deliver the raw fabric is insufficient to also allow for the manufacturing of the completed styles. In this situation, the delivery of customer orders is often delayed and, at times, such customer orders are cancelled because they have not been delivered on time. Thus, the acquisition of raw materials and, specifically, fabrics is a significant challenge to the scheduling activities.

The fourth factor which has a major influence on the production planning and scheduling function is that related to capacity. Capacity in most garment manufacturing companies is mainly dependent upon the number of sewing operators and similar manufacturing personnel. The capacity planning and management of the work force is a significant challenge with respect to either the achievement of sales in excess of those originally projected or in the problems of being in an over capacity situation with capacity in excess of demand.

3.4.2. Field Trips to U.K.and Finland:

In the early stage of this research I visited Alexandra in the U.K., and two companies in Finland. My trip to Alexandra had been arranged when the Managing Director and Plant Manager had visited the Canadian company(Tan Jay). From several hours of discussion and study of each department in Alexandra the extensive field notes and sample documents were collected. A few weeks later I visited Finland. The trips to the Finnish companies of Pola Paita and Verke had been arranged by the consulting firm of Eriksson Associates. I had met one of the senior consultants in Winnipeg. I spent a day at each of the two Finnish companies, and collected detailed notes describing each company, and specifically the nature of their scheduling function, and the production cycle.(i.e. design, samples, marketing, sales, material acquisition, production, distribution). One year later I again returned to

Alexandra to confirm my understanding of the differences between Alexandra and the other companies studied.

From the analysis of the field data from Alexandra, Pola Paita, Verke and my detailed knowledge of the first Canadian company(Tan Jay), I prepared a Descriptive Outline of the characteristics that identified the similarities, differences, and concisely described the main characteristics of this type of business. This comparison is presented in Figure 3.4.

COMPARISON OF COMPANIES IN RESEARCH

COMPARISON CRITERIA	TANJAY	ALEXANDRA	VERKE	POLA-PAITA
A. RESEARCH PERIOD: -				
1. PERIOD STUDIED	NOV 1984 - JUNE 1987	JUNE 1984 - JUNE 1985	JUNE 1984	JUNE 1984
B. COMPANY BACKGROUND -				
1. OWNERSHIP	2-WORKING PARTNERS	FAMILY WITH 30% PUBLIC SHAREHOLDINGS IN 1985	FAMILY OWNED	FAMILY OWNED
2. MAIN MARKETS:				
SEX	FEMALE	MALE/FEMALE	FEMALE	FEMALE
AGE	25+	20+	25+	25+
PRICE	MID RANGE	LOW - MID	LOW - MID	LOW - MID
FABRIC TYPE	SYNTHETIC & NATURAL	SYNTHETIC	SYNTHETIC	SYNTHETIC & NATURAL
FASHION CLASS	CAREER & ACTIVE CASUAL	UNIFORMS	CAREER & CASUAL	CAREER & CASUAL
3. SALES FORCE	OWN	OWN	OWN	OWN
4. MARKETING/PRODUCTION STRATEGY	"PRODUCE TO SALES"	"PRODUCE TO FORCASTED SALES", CARRY INVENTORY	"PRODUCE TO SALES"	"PRODUCE TO SALES"
5. CUSTOMER BUYING PATTERN	SEASON, 25% REPEATS	ANNUAL, 80% REPEATS	SEASONAL ONLY	SEASONAL ONLY
6. ORDER SHIPPING DISCIPLINES	SHIP COMPLETE PRIOR TO ORDER CANCELLATION DATE	SHIP 80% IN 1 WEEK, ALLOW BACKORDERS	SHIP COMPLETE PRIOR TO ORDER CANCELLATION DATE.	SOME BACKORDERS MOST SHIP COMPLETE
7. UNIT SALES/YEAR	2.5-3.5 MILLION	3.5 MILLION	1.5 MILLION	1.0 MILLION
8. MODELS/YEAR	1500 100% NEW DESIGN	350 10% NEW DESIGN	300 100% NEW DESIGN	200 100% NEW DESIGN
9. MODEL LIFE TIME	1 SEASON	2-4+ YEARS	1 SEASON	1 SEASON
10.DESIGN LEAD TIME	8-12 MONTHS	4-8 MONTHS	8-12 MONTHS	8-12 MONTHS
11.NO. OF PLANTS	4	2	2	2

Figure 3.4
Comparison of Four Companies

12.NO. OF SEWING LINES	22	24	14	8
13.CONTRACTORS USED	2-10	0	1-4	1-2
14.IN-HOUSE CAPACITY FLEXIBILITY	-30% TO +30%	-5% TO +5%	-5% TO +5%	-5% TO +5%
15.WORKFORCE FLEXIBILITY	LAYOFFS ACCEPTABLE	LAYOFFS NOT ACCEPTABLE	LAYOFFS NOT ACCEPTABLE	LAYOFFS NOT ACCEPTABLE
16.NO. OF EMPLOYEES	700	700	750	600
17.WORK-IN-PROCESSING	2-5 WKS	2-4 WKS	2-4 WKS	2-4 WKS
18.RAW MATERIAL SOURCING	BUY TO TOTAL REQ'TS	BUY TO FORCAST REQ'TS, CARRY FABRIC INVENTORY	BUY TO TOTAL REQ'TS	BUY TO TOTAL REQ'TS
19.NO. OF FABRICS USED PER YEAR	200-300	14	30	50
C. PRODUCTION PLANNING AND SCHEDULING				
1. LONG RANGE PRODN PLANS ARE PREPARED BY: -	PRESIDENT, V.PRES.	MANAGING DIR., GEN. MNGR, DIR.PRODN	MANAGING DIRECTOR, VP MARKETING, DIR MANUF.	VP FINANCE/ADMINISTRATION
2. LONG RANGE TIME HORIZON	12 MONTHS AHEAD & FISCAL YEAR	12 MONTHS AHEAD & FISCAL YEAR	12 MONTHS AHEAD & FISCAL YEAR	12 MONTHS AHEAD & FISCAL YEAR
3. SALES ESTIMATES PREPARED BY:	PRESIDENT, VP SALES, SALES MNGRS	MANAGING DIR, VP MRKT'G,GEN MGR	MANAGING, DIR, DIR MRKT'G,	VP,DIR MRKT'G
4. SALES ESTIMATE CYCLE	MONTHLY THEN WEEKLY IN SELLING PERIOD	MONTHLY	MONTHLY THEN WEEKLY IN SELLING PERIOD	MONTHLY THEN WEEKLY IN SELLING PERIOD
5. MID/SHORT TERM SCHEDULING PERFORMED BY:	SCHEDULER & ASSISTANT UNDER DIR OPERATIONS	MANAGING DIRECTOR AND VP ADMIN, DIR MANUF.	DIR MANUFACTURING AND DIR SYSTEMS	DIR MANUF, DIR MARKETING, AND 6 PLANT SUPERVISORS
6. SCHEDULES REVIEWED BY	SCHEDULING COMMITTEE: VP.FINANCE, DIR MANUF., DIR.OPERATIONS, SCHEDULER	MANAGING DIRECTOR AND	MNGT COMMITTEE VP ADMINISTRATION	SCHEDULING COMMITTEE

7. FREQUENCY OF REVIEWS	WEEKLY	MONTHLY	WEEKLY	WEEKLY
8. FREQUENCY OF SCHEDULE REGENERATION	DAILY, IF REQ'D USING DSS	MONTHLY	WEEKLY	WEEKLY
9. METHOD OF SCHEDULE REGENERATION	LOTUS MODELS ON PC-AT	SELDOM NEEDED, MANUAL	SIMPLE BUT LENGTHY BACKWARD SCHEDULING	MANUAL
10. LONG TERM SCHEDULE PERIOD	16-32 WEEKS	8-12 WEEKS	16 WEEKS	8 WEEKS
11. MID/SHORT TERM SCHEDULE PERIOD	0-16 WEEKS	4-8 WEEKS	1-16 WEEKS	0-8 WEEKS
12. SHORT TERM SCHEDULE PREPARED BY:	SCHEDULER	CUTTER	DIR.SYSTEMS, DIR PRODN, DAILY PRODN PLANNERS	SCHEDULING COMMITTEE
13. SHORT TERM SCHEDULE PERIOD	SAME AS MID TERM	-0-4 WEEKS	0-1 WEEK	0-1 WEEK
14. PLANT CAPACITY UNITS MEASURED IN	STD MINS BY LINE	UNITS BY LINE & PRODUCT TYPE	AVERAGE STD MINS BY LINE	STD MINS BY LINE
15. SHORT TERM PROD DEMAND UNITS MEASURED IN	STD SEWING MINS BY MODEL	UNITS BY PROD TYPE	AVE SEWING MINS BY PRODUCT TYPE	SID SEWING MINS BY CUT
16. CUTTING ORDERS PREPARED BY	PRODUCT MANAGERS UNDER DIR OPERATIONS	CUTTER	DIRECTORS COMMITTEE	COMMITTEE OF PRODN MNGR SUPERVISORS
17. DEGREE OF SCHEDULING CONTROL OVER ISSUING OF CUTTING ORDERS	LIAISON ONLY	DIRECT RESPONSIBILITY	DIRECT INVOLVEMENT	DIRECT INVOLVEMENT

3.4.3. Observations

The field trips to the U.K. and Finnish companies were initially undertaken as exploratory ventures to simply learn whatever I could. Upon reflection, the data from these three companies has been very important in my understanding of the context and relevance of the scheduling function to companies in the GMI. The more important observations resulting from the study of these companies were:

Pola Paita and Verke:

1. In Finland the two companies were in the same type of business as Tan Jay, that being the fashion and seasonal markets. Thus each season had its own new collections of styles reflecting the latest fashion trends. Since any inventory of unsold items could not be sold in a later season, production was planned only to meet the customer orders. This type of production management is called "Make-to-Order"(Wild 1985).
2. One of the main characteristic shared by Pola Paita, Verke and the three Canadian companies studied is the challenge of managing a few basic contradictions in this segment. These contradictions can be described as follows:
    1. Sales cannot be forecast accurately at the detailed style level, thus capacity and material requirements cannot be planned accurately.
    2. The manufacturing lead time, i.e. the interval between receipt of customer orders and delivery date, is less than the material acquisition lead time.

3. The contradictions involve the management of:
    1. Customer Orders
    2. Raw Materials
    3. Capacity
    4. Customer Deliveries
3. The study of the three Canadian companies and the two Finnish companies identified the strategies employed to achieve some success at managing these contradictions. The resolution of these contradictions is based on the specific flexibility that is inherent in each country.
4. In Finland, due to the restrictions of the labour laws, a shortage of skilled workers, and the implied responsibility of the corporate sector in each community, the companies employ the following strategies:
    1. Maintain stable workforce
    2. Sell to Capacity, updating the production and delivery plan on an daily basis to reflect the latest sales, material and delivery plan. (During markets and selling periods, the schedules are updated hourly.)
    3. Use Sub contractors when sales exceed capacity
    4. Manage material acquisition to obtain maximum flexibility by:
        1. Producing 80% of their fabric requirements(Verke).
        2. Paying a premium for key fabrics to obtain quantity and delivery flexibility.
    5. Delay production decisions until the last minute, to consider the latest information.

5. In Canada, due to more flexible labour laws, and a larger more flexible work force, Tan Jay and the CASE II and III companies employed the following strategies:
   1. Sell to Market Potential
   2. Increase Capacity by:
      1. Increase hours/day,i.e. overtime
      2. Increase shifts/day i.e. second shift of different workers(Note: many Canadian workers maintain two jobs working both day and night shifts for two companies)
      3. Use Sub contractors when necessary,
   3. Manage Customer Deliveries by partial shipments, thus obtaining extended delivery dates,
   4. Manage Material Acquisition to obtain flexibility by:
      1. Make bulk commitments with interim colouring dates,
      2. Use Air Freight to avoid 2-4 weeks shipping delay,
      3. Spot buying of essential fabric from mills or other manufacturers(at premium prices).
   5. Substitute similar styles for sold-out items to lower priority customers.
   6. Short ship lower priority customer orders.
   7. Delay production decisions until the last minute, to consider the latest information.
6. In both the Canadian and Finnish companies studied, the scheduling function was given the task of managing these contradictions and strategies. Due to the variability of sales and the resulting variability of

material and capacity requirements, managers were continually working on new material and capacity plans and arrangements. These plans and uncertain arrangements created a very demanding and dynamic environment for the scheduling function. During certain periods the schedule changed several times a day. Each material and capacity plan required the analysis of the options and identification of the most desirable outcome.

Alexandra:

1. Alexandra produces a wide range of uniforms for workers in hard wearing environments such as factories, to semi professional occupations such as airlines, and banking. There is very little fashion content and seasonality in the collection of style produced. This results in a very stable product line with less than 10% of their styles being revised from year to year. In contrast, the fashion companies employ up to 25 staff working in design, while Alexandra have 2.
2. This lack of seasonality and fashion content result in continuous demand for each item throughout the year and from year to year. This allows Alexandria to carry inventory of each item and to fill orders from stock. At the time of my visits, their goal was to keep sufficient stock on hand to fill orders within 3 days. This meant that they never wanted to be out of stock, and thus their strategy was to schedule production to maintain adequate inventory levels. This method of production management is called "Make for Stock" (Wild

1985).

3. The scheduling function was preformed as follows:
   1. Forecast sales of all items(based on slight seasonality and recent trends),
   2. Determine potential out-of-stock styles,
   2. Sequence the styles to be produced,
   3. Determine the quantities to produce, usually sufficient to satisfy 2-3 months of demand.
4. This scheduling function was performed by the Managing Director and the Plant Manager once a month. They used computer generated reports to make these decisions.
5. Material Acquisition was planned and performed on a quarterly basis with large quantities of common fabric stored as raw material inventory.

3.5. THE PRODUCTION CYCLE

3.5.1 Detailed Product Flow

The product cycle is the term used in this discussion to describe the main activities that occur in the industry to bring a product from conception to delivery for customers.

The "product cycle" illustrated in Figure 3.5 is for a class of product with the following characteristics:

1. Seasonal demand.
2. Fashion item, possibly never produced again.
3. Component of a "line" of related items - related by styling, color, fabric, or fashion.
4. Non-inventory item: due to its seasonal and fashion nature no stocking of inventory is planned.
5. Materials used in production are not off-the-shelf and

must be ordered ahead of need - lead times may vary from 2-12 months.

6. The market is a consumer market through a variety of types of retail outlets not owned or controlled by the manufacturer.

In Figure 3.5 the main functions are labelled A to F, with the flows [1] to [11], which are briefly described below:

A. Product Development a fashion concept including size of the line(no. of styles), styling, fabrics(10-30), colours, timing of deliveries.

Flow [1]: Initial sales estimates are prepared and communicated to other areas in the company

Sample garments are made and modified. Production considerations of each sample are determined including the bill of material and list of operations. Samples are costed and corresponding retail prices identified. The "line" is assembled and each sample is rejected or included in the final line.

Flow [2]: Final sales forecasts are prepared and communicated to other areas of the company. These estimates are by item at this time. Color percentage breakdowns are also prepared to yield a unit estimate by style and color.

Flow [3]: The final "line" of garments are given to the Sales department for selling.

Flow [4]: Over the Selling period(4 -12 weeks), daily or weekly revised forecasts, by style, are provided to the key planning departments.

Flow [5]: Scheduling, and Purchasing work together to determine requirements, availability of resources and timing.

Flow [6]: Sales informs Purchasing of the colour requirements by fabric. Purchasing then orders the colouring of the fabric in the mills.

Flow [7]: As capacity plans are prepared and revised and contracting is arranged, Scheduling and Manufacturing work very close together. The schedule for the short term becomes the guide for introducing work into production.

Flow [8]: Cutting Orders are prepared and given to Manufacturing.

Flow [9]: To achieve customer deliveries, Scheduling, Manufacturing and Distribution work together to meet short term delivery dates.

The production flow accompanying the Product Cycle is illustrated in detail in Figure 3.6.

Figure 3.5

Product Cycle

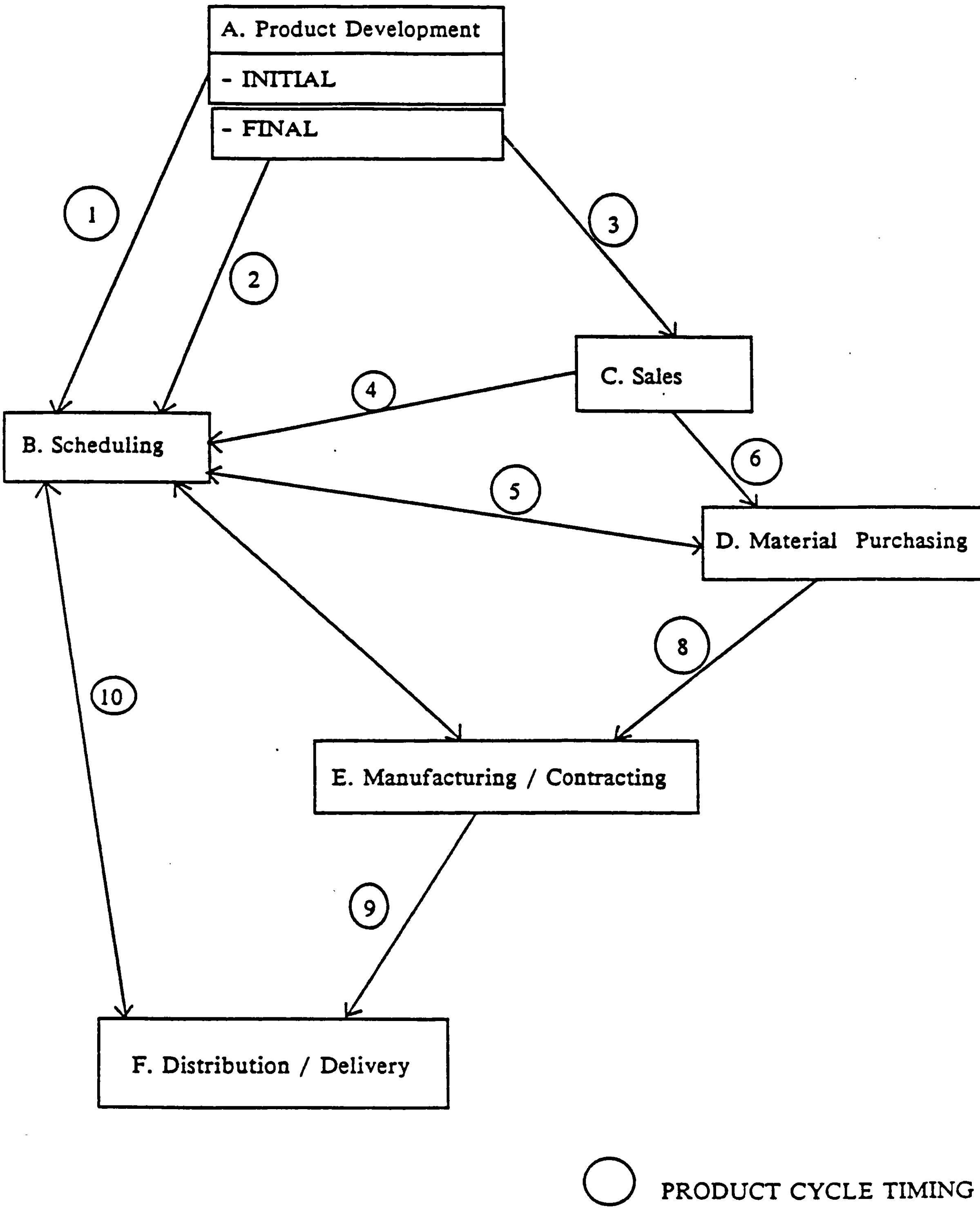


Figure 3.6

Production Flow

Step # Decision	Info Flow
1. Sample is <u>in</u> "line"	"Approved Specifications" pattern, fabric, colors, dimensions, bill of material production method, designated facility
2. Purchase fabric (colors) (receive fabric) & (Also findings)	"P.O./Invoice"
3. Approval to use	"Inspection Report"
4. Issue Cutting Order (for x units in y colors & z sizes) (up to 3 cutting orders may be issued over a 4 week period)	"Cutting Order" & "Marker"
5. Send cut pieces to facility "P" for sewing etc. (Decision may have been made prior to this stage on which facility to use	"Approved Specifications"
6. Manufac. Completed send completed garments to Distribution "Quality Control & Inspection"	"Q/C Inspection Report" "Receiving Report"
7. Pick/Ship Customer Order	"Picking Slip/Invoice"

Physical Flow

3.5.2. An Example of a Scheduling Problem

There are many reasons why delivery dates are not met. Usually the most immediate reason or cause is that production was not completed on time. This is seen as the cause only because it is the main focal point for the culmination of many other actions, any one of which may also have been late. The following example illustrates this complexity:

In the overall seasonal plans, for the upcoming Summer 1984, Fabric K21 was expected to arrive Dec. 1, 1983. It arrived January 4, 1984. The "line", that the K21 models were in, was expected to ship March 1st, 1984. The customer orders started being shipped March 7 and were not completed until April 1, 1984.

The cause of this delivery problem could be said to be late fabric delivery. Further investigation, however, revealed that the mill was on strike for two weeks in September 1983; another cause, in the "cause-effect" chain. The strike was a known situation to the designers and the schedulers. In spite of this knowledge the designers were late in finalizing the number of models that would use this fabric. Therefore, the sales estimation process was late. This resulted in the Purchase Orders being sent a week late. Scheduling expected the fabric to be two weeks late, but underestimated the "Customs" delays over Christmas. Once the fabric did arrive, a few staff in the Inspection department were on vacation so the fabric sat for a few weeks.

After the line was finally shipped a meeting of all the key managers was called. Consider for a moment the atmosphere of the meeting that was called to review this situation. I attended as an observer. The representatives from design, scheduling, purchasing, distribution, production and senior management participated in an emotional attempt to identify and resolve the problem. The meeting was first interrupted when the senior executive had to accept an important call from a key customer to accept a "late" order for 1000 units. Then the purchasing manager was given a telex that another shipment was going to be late - he left to deal with that problem. Other managers took the opportunity to depart to deal with other crises. Within five minutes the room was empty except for me.

This is what the "real" world of the garment business is. It is competitive, dynamic and demanding. There are never enough hours in a day to keep on top of every situation. Every person has a critical function.

3.5.3. Impact of Poor Planning and Scheduling

From the viewpoint of the companies involved in this type of business the implications of poor production planning and scheduling are very serious and may lead to severe financial difficulties if they persist.

A review of these implications also leads to an identification of performance criteria in measuring the quality of production planning and scheduling. The main implications of problems in this area are:

1 Late Customer Deliveries resulting in:

1. Customer cancellation of orders,
2. Customer returns of unwanted merchandise,
3. Retail losses by the customer leading to smaller

future orders, and

4. Lost credibility and confidence by customers.

2. Lower Production Efficiency (higher costs) as seen in:

1. Uneven work-in-process levels; too high in some facilities (high WIP carrying costs), too low in others (resulting in low worker efficiency),
2. Idle capacity with continued overhead costs,
3. Worker lay-offs, followed by re-hiring, creating an unstable work force with the more skilled workers leaving and lessor skilled workers requiring high training costs,
4 Unplanned use of costly contractor facilities.

The net effect of these production difficulties is higher costs per unit.

3. Organizational Stress throughout all departments:

1. Creating crisis management tendencies,
2. Limiting growth opportunities for the company, and
3. Generating an atmosphere of instability and poor management.

This situation leads to weaknesses in other departments being blamed on "poor scheduling" without being properly addressed and solved.

In contrast, when production planning and scheduling responsibilities are being fulfilled effectively customer relations are good, production costs drop or are maintained at competitive levels and management has the time to solve other problems and capitalize on growth opportunities.

The conclusions which I wish to emphasize at this time and which have a bearing upon future potential solutions are as follows:

1. A significant portion of the scheduling function is involved in the identification, analysis, and solution of problems of many types: operational, staffing, group interactions, organizational, and system oriented.
2. A scheduling system solution must be designed to support the identification, construction, analysis, and solution of problems; especially operational problems. In addition, such a solution must be designed with an awareness of the other types of problems identified above and their constraints on the environment in which solutions are to be analyzed and implemented.
3. There is nothing so constant as change. Organizations, people, committees and the working environment of this garment company were in a constant state of evolution.

3.5.4. Summary of Scheduling Scope

The production planning and scheduling challenge is to coordinate the activities, material arrivals and production facilities in such a manner to achieve delivery schedules quoted to the customers by merchandising and sales personnel.

More specifically, the activities coordinated and scheduled by the Scheduling department are as follows:

1. Determination of when fabric has to be ordered in bulk, ie. the greige contract,
2. Determination of when the fabric must be coloured into specific colours related back to either original sales estimates, revised sales estimates, or customer orders

which may be confirmed at that time,

3. Coordination or expediting of fabric to ensure that delivery schedules of fabric are met,
4. Determination of required production capacities of specific types of manufacturing; corresponding to the types of garments being manufactured,
5. Identification of production under or over capacity situations as a result of fabric delivery expectations and customer delivery schedules of finish garments,
6. Identification of appropriate options when "over" or "under-capacity" situations exist,
7. Coordination of the introduction into production of the actual fabric for each style in conjunction with the actual fabric arrivals into the company's premises and the actual available capacity at the time the fabric arrives or at the time the production is to be begun,
8. Monitoring and follow-up of all production schedules at the detail level to ensure the schedule is followed or as uncontrollable factors dictate, change the schedule,
9. Revision of the schedule in order to accommodate the new factors as they change from week to week or day to day.
10. In addition to these production planning and scheduling activities, it is also necessary to provide a long term planning activity to anticipate and indicate appropriate action in the longer term with respect to future production requirements. Often these requirements are as a result of management decisions in a specific direction, ie. to acquire additional

contracting.

11. In the contracting situations, the Scheduling function must co-ordinate the activities so that contracts can be arranged on a long or short term basis satisfactory to the company. Scheduling must ensure that the contract can be filled with the required number of units of production contracted to such manufacturers.
12. Scheduling must also monitor fashion changes and trends in order to ensure that the internal facilities of the company are appropriately fined tuned or modified as fashion trends dictate changes in manufacturing methods.

Thus the planning and scheduling activities are concerned with the long term implementation of management directives, the implication of fashion trends to manufacturing methods, the appropriate re-adjustment of internal facilities and the more immediate or near term (0-12 months) of the actual execution of the manufacturing of the specific "line" or "lines" as they leave the product development cycle and are turned over to Scheduling for production to achieve the required delivery dates.

The general type of production described in this chapter is usually referred to as "make to order" (Wild 1985) or as "the selling situation" (Lockyer 1983). This operational approach is in contrast to the Marketing situation of "making for stock".

3.6. THE FRAMEWORK OF PRODUCTION/OPERATIONS MANAGEMENT

3.6.1 Overview

The field of Production and Operations Management is a broad one covering all aspects of manufacturing including organizing, planning and management of production, warehousing, and distribution facilities. Thus, it has considerable relevance to the study of the garment scheduling problem. The base for the literary review included texts by Lockyer (1983), Buffa (1968), Stevenson (1982), Wild (1985), Bensoussan et al (1983).

3.6.2. P/OM Description of the GMI Scheduling Problem

The production/operations management literature (P/OM) decomposes the general scheduling problem into the following sub problems:

1. Sales forecasting and Order Processing
2. Capacity Planning
3. Material Acquisition and Control
4. Aggregate Planning and Scheduling

Each of these is discussed from the viewpoint of the garment problem. The methods suggested for the execution of each function are identified in a manner that facilitates comparison with the three cases.

3.6.2.1. Sales Forecasting

The importance of sales forecasting to the scheduling function is difficult to overstate. As Stevenson(1982) identifies two general approaches to forecasting, "qualitative and quantitative."

"Qualitative methods consist mainly of subjective input, which often defies precise numerical description, such as consumer surveys, sales force composites, executive opinion, Delphi technique, and/or panels of experts.

Quantitative methods involve either the extension of historical data or development of associate models which attempt to utilize causal variables to make a forecast." (p. 73)

In the garment manufacturing problem the nature of the business itself dictates that a combination of both approaches must be used. In the first case, qualitative judgment plays a primary role because the products are not repeat products which have been manufactured and sold in the corresponding time period of previous years. Thus the fashion nature of the business necessitates that new product lines be developed for every season of every new year. Historical information which could accurately depict new situations is not available at the individual model level. In addition, because of the fashion nature of the business, grouping of the products from past history is again difficult in that one year a certain type of fabric may be more important as a fashion statement then the next year. Thus the judgment of the senior marketing and merchandising personnel is the primary input into forecasting for future sales.

Another important consideration in sales forecasting is the planning horizon time(Buffa 1968).

In the garment industry the planning horizon depends on factors such as the behaviour of the markets and raw materials suppliers and also on the nature of the internal operations of the business. In the case of the garment industry, the planning horizon is critical in that at any one time the fashion line which is being developed will not be produced and available for retail sales until approximately 12 months into the future. Therefore, the critical planning horizon begins one to one and a half years prior to product delivery. Further, in the case of foreign fabric mills where the fabric is often made specifically to the designs prepared by the garment manufacturing companies, commitments must be made as far in advance as six to ten months. Similarly, where production is being booked in foreign countries, such as in the Far East, production commitments must also be made as far in advance as ten months prior to delivery. Clearly the combination of a long planning horizon timing into the future as well as the lack of a consistent pattern of previous demand to assist in the forecasting exercise creates a high risk and a high degree of uncertainty for the preparation of these forecasts.

3.6.2.2. Capacity Planning

The challenge of capacity planning in general is recognized as one of the most important activities in an organization. Stevenson (1982) indicated the following:

> "Capacity decisions are perhaps the most fundamental of all the design decisions managers are called upon to make." (p. 135)

While Wild (1985) considered the following:

> "Both activity scheduling and inventory management decisions may be considered subsidiary to capacity management. A particular approach to, or strategy for, the management of capacity will often be implemented largely through scheduling and inventory decisions." (p. 185)

Wild(1985) further indicates the essence of the garment capacity planning problem when he states that:

> "It is the uncertainty of demand level which gives rise to this problem (planning and control of system capacity)." (p.186)

The uncertainty of demand is caused by either

a) Uncertainty about the number of orders to be received; and/or

b) Uncertainty about the amount of resources required for the satisfaction of particular customers' order.

In the garment manufacturing situation both (a) and (b) apply since the capacity requirement is the summation of the units of each model ordered by each customer, times the time required for one unit of a given model.

Wild(1985) understand the cyclic nature and iterative exercises necessary when he states:

"While it is convenient to consider capacity planning as occurring in two stages i.e. determination of average level and planning for variations above this level, these two aspects are clearly interdependent." (p. 186)

Wild(1985) addresses two basic strategies for capacity management:

- "Strategy 1: Provide for efficient adjustment or variation of system capacity.
- Strategy 2: Eliminate or reduce the need for adjustment in system capacity."

For capacity variation Wild(1985) states:

"For capacity increases subcontract work, reduced material content, substitute more readily available material, increase supply schedules, transfer from other jobs, defer maintenance of equipment, increase work force size and working hours."

For capacity reductions Wild(1985) suggests:

"Retrieve work from subcontractors, reduce supply schedules, transfer materials to other jobs, advance machine maintenance schedules, reduce the hours worked by short shifts or holidays, or laying off of staff or transferring staff."

For adjustments in system capacity, Wild(1985) suggest the following approaches:

"Maintain excess capacity to accommodate demand increases, accept loss of customers without increasing

> capacity, keep customers waiting until production can be completed with existing capacity, create inventory of sales items in order to handle demand increases." (p. 188)

The elements most applicable to the garment industry, and in fact those that are used, relate mainly to subcontracting, work force size, and hour compliment functions. Transferring materials does not apply in that the materials have been purchased for specific models. Similarly, substituting more readily available material is not relevant since sales are particular to specific raw material fabric. Increasing supply schedules or reducing supply schedules are often not achievable because of previous contractual commitments with suppliers.

With respect to Strategy 2, the elimination or reduction of a need for adjustments in system capacity, Wild suggest the following approaches:

> "Maintain excess capacity to accommodate demand increases, accept loss of customers without increasing capacity, keep customers waiting until production can be completed with existing capacity, create inventory of sales items in order to handle demand increases." (p. 188)

Each of these strategies is relevant depending on the specific situation. In the Canadian companies researched, excess capacity is not generally maintained and it is believed that excess capacity with respect to labour is not efficient or profitable. Planned capacity kept in a potential or unused state is often carried out though. Accepting loss of customers, Wild's second suggestion is in fact carried out although reluctantly. His third suggestion of keeping customers waiting is in essence the major problem identified because in carrying out this strategy, delivery dates are not achieved which in fact are of primary importance. Thus, this is not a favourable option. His final suggestion of carrying inventory, again in the fashion industry, is not highly favoured because of the potential for being left with this inventory after the fashion period has been completed or alternatively having to sell such extra inventory at considerably reduced prices.

In England, Alexandria reduced the need to adjust capacity by using inventory stocks, but in this case, the market not being fashion related the likelihood of being left with unsalable merchandise is considerably reduced. In the companies studied in Finland a combination of strategy "1" through the use of contractors, holidays and overtime as well as strategy "2" in the loss of trade are carried out.

Summary

The primary means of adjusting capacity, of a significant nature, is through the use of subcontractors. The difficulty in doing this, however, is that a higher cost per unit often results and the approach is least reliable, most expensive, and least flexible when it is needed most since the need for greater capacity is often associated with a general increase in total industry demand. At such time, potential sub-contractors will also be extremely busy (Wild, 1985). Further the difficulty in arranging sub-contractors in the garment manufacturing situation is made more complex because of the uncertainty of sales projections and the uncertainty of demand until such time as customer orders are received. At this time, the receipt of these orders often does not allow sufficient lead time to arrange for adequate capacity additions. In addition, if sufficient lead time appears to be available for the arrangement of capacity extensions through sub-contracting, sub-contractors themselves are often unwilling to commit, since by the nature of their business they do not plan sufficiently in advance to guarantee the availability of production space. Further, sub-contracting by its nature is extremely risky and at any one time a commitment from a sub-contractor for several months into the future may in fact not be achievable because the sub-contractor has either failed to stay in business that long or does not have the required capacity available when needed because of more profitable demands for sub-contracting services. From another viewpoint the capacity planning problem defined by the objective of obtaining excess capacity to meet increased sales demand is in a sense an artificial problem created by the desire to achieve sales levels in excess of those originally intended in the original financial plan. Artificial as this may be, it is the essence of entrepreneurship and customer satisfaction leading to market penetration and market growth and thus it cannot be minimized.

On the other side of the capacity picture when capacity reductions are necessitated these are also done in the light of uncertain demand until customer orders can be ascertained. In the Canadian companies studied, when demand reductions are necessary, staff lay-offs and/or plant closing can be achieved without too much government intervention. They are, however, undesirable with respect to the reputation of the manufacturer in the labour force market and often lead to bad labour-management relations. When necessary, however, they are done with the knowledge that when increased capacity is required many of the established and experienced work force are often unavailable and building capacity back to previous levels is difficult and requires considerably more time because of staff unavailability and retraining. Short term plant closing and plant renovations as well as shift reductions can be carried out in some cases without loss of a stable workforce.

3.6.2.3. Material Acquisition and Control

The problem of materials management and control in the garment industry for fashion merchandise is primarily one of sales forecasting related to raw materials which require long lead times for the production and delivery of raw material fabrics. In Lockyer's(1983) discussion he fails to identify the point that total material requirements are not known precisely until customers' orders have been received and the products have very few common fabrics and thus very few models are made in the same fabrics and even fewer of these have the same components. Thus purchase of fabric must be related directly to the specific models that are to be produced in that fabric.

In current technology material requirements planning (MRP) is seen as a common means of material management and control. This useful technique considers that the finished product is exploded into raw materials and components which sets out the logical and numerical relationships between the finished products and their constituent of assemblies and components (Lockyer, 1983).

3.6.2.4. Aggregate Planning and Scheduling

In general terms, aggregate planning refers to the concept of determining the capacity requirements of all products for any given time period. Wild(1985) views aggregate planning as:

> "The term aggregate planning is often employed in the capacity context. The implication is that such planning is concerned with total demand i.e. all demands collected together." (p. 193)

He further states:

> "This is of relevance only in multi-channel systems where different goods or services are provided, and in such cases aggregate or capacity planning will seek to estimate or measure all demands and express the total in such a way as to enable sufficient of all resources (or total capacity) to be provided."

In this respect aggregate planning is carried out in the garment industry in the following manner. From the initial sales forecasts and through the process of determining approximate ratios for each garment type, totals for all products by garment type can be estimated. Initially these estimates are at the level of garment types i.e. pants, shorts, skirts, jackets, blouses, sweaters, coats, bathing suits, etc. The difficulty in this level of detail, however, is that a specific garment may have several design features which eliminate several potential manufacturing line options. More specifically consider that a jacket may be lined or unlined and thus a specific sewing line which handles unlined jackets would not be a potential option for manufacturing the lined jacket. These kinds of design details are not known often at the time of the original estimating process. Consequently, the aggregate nature of the planning at initial forecasting time is another element of uncertainty with respect to capacity planning.

It is not until specific product designs have been completed that sales estimates and forecasts can be made at the model level. Once these forecasts are available at the model level then each model can be evaluated to determine the most appropriate sewing line to manufacture that model on. Further, by knowing the features of each model, alternate production sewing lines and contractors can be assessed. It is, at this point in time, that the scheduling function and detailed capacity planning functions begin. In general terms Wild refers to this phase as "activity scheduling". (It is also referred to as activity planning.) It is concerned with the fixing of the specific times when a specific model will enter specific production stages or machines. Wild describes this problem as follows:

> "The manner in which the activity scheduling problem is tackled will largely depend on...if an operating system is working in anticipation of demand...(or)...to satisfy individual customers "due date" requirements." (p. 203)

In the garment situation, the specific assignment of garments to sewing lines is carried out when the product line has been finalized. This however is still in advance of the beginning of the selling period. Thus there is uncertainty and inaccuracy in the sales estimates.

3.7. RELATED SCHEDULING RESEARCH

3.7.1. Computerized Production Planning:

A number of authors have attempted to develop computerized systems to assist the production planning and scheduling function, in general(Malko 1983, Bensoussan et al 1983, Proud 1983). A few have addressed the garment industry specifically.(Martignago 1982, Mellinger 1983, Kurt Salmon 1985).

These systems fall into two categories of systems:

1. General MRP systems based on multiplying the units on order by the respective bills of material and work tasks to determine total requirements. The totals are then compared to the available and a net over or under position identified. Some of these systems group all orders into one time period while others relate the requirements to multiple time periods. These systems are batch processing systems, which because of the volume and complexity of the calculations often require hours to complete one cycle. Recalling that one of the realities is the need for multiple updates per day, these systems do not fulfil this requirement.
2. Mathematical based planning solutions, integrated into computer programs. A good reference for such an approach is Bensoussan et al(1983). While identifying theoretically optimal solutions for a number of cases of demand and costs of inventory and production, the basic assumptions do not allow for inaccurate forecasts, short delivery lead times, and inaccurate material requirements. The basic assumption is that accurate long term plans can be made at the aggregate level, that will be perfectly met at the detailed, short term level. While the specific models developed did not fit the GMI scheduling problem, I believe the theories and approached may have promise for future extension to fit the problem studied in this research.

One of the results of the study of other scheduling systems has been the realization that each such system can be seen to be composed of two models, namely:

1. The Systems model, described by many general and specific attributes of the system environment,
2. The Scheduling Model, whether it be mathematical, MRP or otherwise based on a model representation.

This duality of models I have used as a foundation for the description and comparison of the three cases described subsequently.

The system model comparison outline is developed in Chapter 4. For the Scheduling model embodied in each case solution, I summarized the P/OM analysis into a Scheduling Model Comparison Outline which is part of the Case Description Outline (CDO) in Appendix A1.

3.8.1. Summary of the Chapter:

The scope of the GMI studied in this research has been defined to be the Seasonal and Fashion based manufacturing of primarily, women's clothing. The nature of the season and fashion business precludes the inventorying of raw materials and finished goods. The forecasting and lead time contradictions lead to a dynamic environment that is inherent to the basic nature of the business. These challenges necessitate a scheduling environment that has the ability to respond in minutes to sales, material and capacity changes, and, to allow the analysis of multiple options of each as each season unfolds.

The three cases analyzed show how three companies approached the solution of these scheduling needs.

CHAPTER 4 - CONVENTIONAL DSS and ES WISDOM - LITERATURE REVIEW

4.1. PURPOSE OF THE LITERATURE REVIEW

The purpose of this research is to provide guidance to Garment Manufacturing Industry(GMI) management and systems designers in the planning, design and implementation of scheduling systems. Within this broad intent is the specific study of the use of Decision Support and Expert Systems technologies to determine if the use of these technologies facilitates the development of successful(useful and usable) GMI scheduling systems. The question of the relationship between DSS and ES technologies and GMI scheduling success has been expressed in the form of the hypotheses defined in Chapter 1. The testing of the hypotheses is approached in this study by undertaking the following process:

1. Review of DSS and ES literature for evidence that the hypotheses are true or false.
2. Review of the DSS and ES literature to define the identifying characteristics of DSS and ES technologies,
3. Identification, from the literature, of the defining parameters of system success for comparison of the results of the three cases.
4. Formulation of the DSS and ES system characteristics and success factors into a Case Description Outline(CDO).
5. Using the CDO to test the hypotheses for each case by determining if each case is an example of a DSS or ES and if the case system is successful or not.

In this chapter I present the literature review and the formulation of the CDO, steps 1, 2, 3, and 4 above. The literature review includes consideration of expert scheduling system research conducted by researchers studying this problem in other areas of application.

The CDO defined in this chapter is then used to compare and evaluate each case in chapters 5,6, and 7. The result of the evaluation of each case is then used to confirm or deny the relevant hypothesis.

4.2. INFORMATION TECHNOLOGY AND DSS

4.2.1. Systems Background

Since DSS and ES systems are generally considered as being within the broad field of Information Technology(IT)(Stair 1984). Thus consideration of the IT field is useful in identifying the foundations of DSS and ES.

Early computer systems processed data and in doing so became known as data processing systems (Stair 1984). Typical outputs of data processing systems were accounting documents, cheques, invoices, etc. These outputs reflected the concept that the data had been manipulated or processed and reproduced as an accounting document or summary listing of the data which had been input. As the early users of these data processing systems began to see that the data could be converted, summarized and transformed into a form that would be helpful in decision making by informing the decision maker(DM), the concept of information began to appear(Stair 1984)). Stair(1984) describes the output of a MIS as follows:

> "This information can relate to internal and external intelligence, and it can assist with the planning,

> staffing, organizing, directing, and controlling. The overall purpose of a management information system is to provide the right information to the right manager or decision maker at the right time." (p.399)

The relationship between data processing systems and MIS is defined as:

> "As defined, a management information system is a specialized data processing system."

Thus the MIS category of systems is a sub-set of the overall concept implied by a data processing system.

4.2.2 MIS Deficiencies

Management Information Systems did not fulfil all the needs of organizations. Nutt (1986) described this situation:

> "Management information systems (MIS) are coming under increasing criticism. Most executives believe that a MIS is essential, but many contend that its performance is not measured up to their expectations." (p.139)

Martin(1984), in his "Information Manifesto" describes these deficiencies as: "The Crisis in Data Processing", and further, "Data Processing is Bogged Down in Problems" (p.3)

File handling methods of data processing systems were a significant limitation to the complexity and power of systems design. To address this problem the general field of data base management began. Data base management systems allowed complex systems integration and the development of terminal based on-line systems. (Martin, 1976)

Traditional MIS development methodology was related to the system life cycles of:

1. Requirements
2. Specifications
3. Design
4. Programming

5. Testing

6. Integration Testing

7. Deployment

8. Maintenance.(Martin 1984)

Other authors such as Hussain & Hussain (1984) considered the development cycle as beginning with initially an identification of a need for a new system followed by feasibility study, systems analysis, systems design, implementation, testing, conversion, operations, evaluation, followed by either redevelopment of the system or ongoing maintenance which could then repeat the cycle starting at feasibility study, systems analysis and design or implementation depending on the nature of the maintenance.

Martin (1984) argues that:

> "Management standards associated with life cycle have acquired the force of law in many organizations. And yet there are obviously great problems associated with the traditional life cycle. The historical life cycle grew up before the following tools and techniques existed:
> - non-procedural languages
> - techniques that generate program code automatically
> - computable specification languages
> - rigorous verification techniques
> - on-line graphic tools for design
> - formal data modelling tools
> - strategic data planning techniques
> - information engineering
> - languages for rapid prototyping
> - languages for end users
> - distributed processing and microcomputers
> - the information centre concept" (p.177)

He further states that any one of these new techniques renders the former concept of the life cycle obsolete.

As the deficiencies of the MIS concepts became apparent, new equipment, theories, methods and tools were being developed to further exploit the emerging opportunities and address the MIS deficiencies.

4.2.3. MIS and DSS Relationship

While MIS technology focused on providing information to management, Carlson(1983) identified that the DSS focus took the next step towards assisting management by providing assistance in the process of decision making.

The relationship between data processing , MIS and DSS systems has several dimensions. From a historical viewpoint, data processing systems were developed first, then MIS systems followed by DSS systems.(Deardon & McFarlan(1966) In those organizations that pioneered the use of computers the MIS systems evolved from data processing systems. As the MIS deficiencies, became apparent, DSS concepts and systems were developed to address these needs. In this respect the foundations of MIS systems are built on the data processing systems and the DSS systems are built on the MIS systems(Stair 1984). Figure 4.1 illustrates the relationships between data processing systems, management information systems and decision support systems.

Figure 4.1 System Relationships
DSS: Assist DM
MIS: Inform Management
Data Processing: Process Data
Data Inputs: Transactions/Files

4.2.4. The Study of Information Technologies

Information Technologies have been studied extensively since the 1960's when data processing computers were given the capability for large mass data storage, complex calculation and simple logic comparisons. From the early beginnings, researchers have focused on the successful use of this technology(Stair 1984, Clowes 1979). Macro and Micro environments have been studied to determine the factors that contribute to the successful IT use(Nolan 1979, King and Kraemer 1984, Powers and Dixon 1973, Bailey and Pearson 1983, Montazemi 1986). The determination of "success" has also been examined from many perspectives(Ein-Dor and Segev 1978).

From my study of these works, my own research (Peterson 1968, 1971, 1983, 1984, 1985, 1986, 1987, 1990), and my experience in the IT field I have determined that the study of a specific type of system can be divided into considerations of the following:

1. The Systems Paradigm; the fundamental purpose and concept of use, eg: Alter(1980) description of a DSS,

2. The System Methodology; how is the system concept transformed into reality, as described by many authors such as (Martin 1984),

3. The System Representation; in the form of:
    1. The System Model composed of the type of user interface(displays, reports, input/output processes, user commands, etc), file structures, languages, and the other components of the technology, and,
    2. The Application Model, composed of the unique data, information and processing rules that define how to use the System Model to provide a useful function to process a payroll, prepare financial reports, maintain customer accounts, or schedule a factory.

4. Success Profile, composed of Success/Benefit Attributes and the Factors that contribute to Success; the attributes define success in general and specifically for the type of system(DSS or ES), while the factors are those conditions and actions that researchers have found are present in successful systems.

In this chapter, I identify the Paradigm, Methodology, System Model and Success from a DSS and ES perspective. The CDO is derived from consideration of the DSS and ES technologies as defined by the Paradigm, Methodology, System Model and Success Profile of each.

The Application Model is the Scheduling Model composed of the functions and representations to fulfil the requirements necessary to solve the problem described in Chapter 3. In Chapter 3, I choose the Production/Operations Management viewpoint of Scheduling to define the subfunctions of Sales Forecasting, Capacity Planning, Material Management, etc. The Scheduling Model for each of the three cases is defined by the specific data, information and processing rules used to attempt to solve the scheduling challenge. The CDO is supplemented by a section called the Scheduling Model, derived from chapter 3.

4.3. DECISION SUPPORT SYSTEMS

4.3.1. DSS Study Plan

This review of the DSS literature identifies accepted and successful DSS practice in a form that can be used to compare and evaluate the three cases, i.e. the CDO. By comparing the three cases with accepted DSS wisdom I intend to achieve the following:

1. To identify if the systems developed were DSS systems,
2. To identify differences that may be specific to scheduling systems,
3. To confirm similarities that appear to be relevant

to the cases, and to scheduling systems,

4. To attempt to identify the Success Profile as the main factors that contribute to the success or failure of the scheduling systems in the three cases.

The study of the DSS field is divided into the sections of:

1. DSS Paradigm; the fundamental concept behind DSS thinking,
2. DSS methodology; the process of designing a DSS, and
3. DSS Representations as embodied in the System Model of a DSS; what are the characteristics of the DSS Systems model
4. Success Profile of DSS systems.

4.3.2. The DSS Paradigm

Alter(1980), Bennett(1983), Stabell(1983), Martin(1976, 1984) and many other systems researchers have contributed to the vast literature on DSS. In general terms a DSS has the purpose of **assisting the decision maker(DM) by providing information and tools to facilitate the decision process.** Carleson(1983) related a DSS to the decision process as follows:

"Decision Makers require support accordingly:
1. Decision makers rely on conceptualizations in making a decision, and a DSS should provide familiar representations, (eg. charts and graphs) to assist in conceptualization.
2. Decision makers perform Intelligence, Design, and Choice activities while making a decision, so a DSS should provide operations which support these activities.
3. Decision makers need memory aids, so a DSS should

provide memory aids which help carry out the decision making process.
4. Decision makers exhibit a variety of skills, styles, and knowledge, so a DSS should help decision makers work in their own idiosyncratic ways.
5. Decision makers expect to control their decision support, so a DSS should provide control aids which help decision makers exercise direct, personal control." (p.20)

Fundamental to the concepts embodied in Carlson's (1983) observations are the general decision making operations for intelligence, design and choice. These are represented by the author as follows:

"Intelligence
- gather data
- identify objectives
- diagnose problem
- validate data
- structure problem

Design
- gather data
- manipulate data
- quantify objectives
- generate reports
- generate alternatives
- assign risks or values to alternatives

Choice
- generate statistics for alternatives
- simulate results of alternatives
- explain alternatives
- choose among alternatives" (p.21)

Bennett (1983) illustrates another important facet of a DSS: the nature of decision making as an unstructured task accordingly:

"By unstructured tasks we mean problems in which:
1. The solution objectives are ambiguous, numerous and not operational;
2. The process required to achieve an acceptable solution cannot be specified in advance;
3. It is difficult to say either in advance or after the fact which user steps are directly relevant to the quality of a decision." (p.48)

Stabell(1983) pinpoints the key design features accordingly:

> "In order to ensure that focus remains on the decision situation, it is important that system use be explicitly linked to the "choice" point in the decision processes. In practice this implies that systems will start by (and evolve from) providing support for the alternative evaluation and comparison phases of the decision process." (p.250)

Summarizing the literature, the relationship between the Decision Process and the DSS concept is illustrated in Figure 4.2

Figure 4.2

Decision Making and DSS

Decision Process	DSS Assistance
Intelligence	Information retrieval and presentation.
Analysis	Manipulation and re-display.
Choice	Identification of comparative or absolute choice indicators. Evaluations of options.

4.3.3. The Designing of Decision Support Systems: DSS Methodology.

Clearly to achieve a set of tools and processes to assist the decision maker(DM) the methodology requires that the DM be the central focus of the design process(Alter 1980). Thus DSS methodology focuses on the **interaction between the DM and the system developer(s)** (Stabell 1983). Martin(1984) views the development process as an exploration of the team members into a new world of a new system. He emphasizes the importance of rapid development languages so the DM does not loose interest between iterations of the emerging system.

Stabell(1983) proposes that the formulation of a coherent **long term system plan** should include an initial specification of which decision processes are not supported and future plans for covering these. The concept of "decision channelling" is described by the author to illustrate an interface architecture that serves to both support existing decision processes and to shift future processes into the more extensive and powerful use of the tools.

Altar(1980) studied DSS **implementation strategies** used by 56 companies and concluded the following:

"1. Divide project into manageable pieces.
- use prototypes.
- use an evolutionary approach.
- develop a series of tools.

2. Keep the solution simple.
- be simple.
- hide complexity.
- avoid change.

3. Develop a satisfactory support base.
- obtain user participation.
- obtain user commitment.
- obtain management support.
- sell the system.

4. Meet user needs and institutionalize the system.
- provide training.
- provide ongoing systems.
- insist on mandatory use.
- permit voluntary use.
- rely on diffusion exposure." (p.165)

Within the above description of dividing the project into manageable pieces, Altar(1980) identifies three situations found in his studies, i.e., prototypes, evolutionary approach, series of tools.

Altar(1980) describes systems which evolve, through a process of "evolutionary development". **Prototyping and evolutionary development** are very similar in their methods in that each identify the necessary iterations that a system will go through to reach its eventual operation.

Prototyping, however, suggests that the prototypes will eventually become implemented as part of a larger system. If on the other hand prototyping continues and the system continues to expand the activity without changing its focus or method, then it has become evolutionary development. This methodology is visualized by Altar(1980) when he states: "If it were possible to create and modify decision support systems in the time span of hours or days, the use of these systems would expand greatly." (p.189)

Bennett (1983) refers to work by Hurst, Ness, Gambino, and Johnson(1983) entitled "Growing DSS: A Flexible Evolutionary Approach". In this report written by practitioners in the field, the authors identify the concept of an **evolutionary system development** process:

> "The evolutionary approach advocated in this chapter suggests user interaction through a readily available terminal, whatever the size or location of the computer system. Interactive responses necessary for both the development and the use of the system. Because the development is evolutionary, fast turnaround between the developer and the DSS is essential; this can only be obtained through human paced, conversational responses." (p.119)

Bennett (1983) discusses a process of system development called **"middle out development"** as a process of problem structuring through prototyping.

Bennet(1983) supports Altar's(1980) **speed of development:and suggests the use of** components of off-the-shelf software, etc. to test the initial routines or the initial concepts of the DSS. After the value of the DSS is proven, specially built efficient routines should replace the less efficient general packages with which the concept had been tested.

Keen and Gambino (1983) identify twelve rules of thumb for **building decision support systems.** These are:

"1. Design the dialogue first.
   a. Define what the user says and sees
   b. Define the representation of data
   c. Adopt a system model which matches the user's conceptional model.
2. Identify the user's special purpose verbs.
3. Identify generic verbs relevant to this DSS.
4. Translate the verbs into commands, and vice versa.
5. Check out public libraries for off the shelf routines.
6. Set priorities for implementing commands for version zero.
7. Support first, extend later.
8. Deliver version zero quickly and cheaply.
   a. Evolve a complex DSS out of a simple version zero
   b. Version zero is intended to establish value and to sell itself.
9. Pick a good user who:
   a. Has substantial knowledge of the task,
   b. Has intellectual drive and curiosity,
   c. Will take the initiative in testing and in evolving version zero, and
   d. Enjoys being an innovator.
10. Recognize data management, rather than commands, as a main constraint.
11. Remember that Brooks is right - programming is 10% of the effort.
12. Know your user at all times.
    Rule 11 may be restated in several ways:
    a. Programming is 10% of the effort
    b. If you want to build a product that will stand by itself, recognize the time and effort needed
    c. Version zero can be built in weeks." (p.151)

Keen and Gambino (1983) identify that their success depended on **supporting a person** not solving a problem or building a model, getting feedback from analyst's direct use of the DSS, and responding to user's ideas and requests.

Moore and Chang (1983) identify several **"Meta-Design"** considerations:

1. The migration of both the system design and the problem understanding over time.

2. Expansion of situation capabilities.

3. The evolution from initial "soft" capabilities into more firmly designed hard capabilities.
4. The use of the system to mould and shape the user's decision making processes rather than copying current processes.

Gorry and Krumland (1983) identify an important concept in the on going discussion of **structured versus unstructured** problems. They indicate:

> "The use of the term "structured" may hide a certain degree of progress, since a problem that at first seems intractable may yield, at least in part, to analysis. When it does it moves into the domain of structured problems, leaving the class of unstructured problems still apparently unaffected by analysis and computer technology." (p.205)

In summary, the fundamentals of the DSS methodology are:

1. Detailed involvement of a strong, motivated DM(Alter 1980).
2. Small team of development staff(1-3), 2 common(Martin 1984).
3. Rapid development language system.(Martin 1984).
4. Start with a simple system and evolve complexity with the DM. i.e. prototyping,(Alter 1980), or evolutionary development(Bennett 1983).
5. Develop DM tools and data representations(Keen and Gambo 1983)
6. Evolve structure to the DM's tasks(Gorry and Krumland 1983)

The main features of the DSS methodology were placed in the CDO to facilitate the classification of the three cases.

4.3.4. DSS Design Representations

4.3.4.1. System Model and Application Model

The analysis of the design representations of a DSS can be divided into a consideration of:

1. the Application Model of the decision environment,
2. the Systems Model of the concepts used to represent the Application Model.

The Application Model is the manifestation of the decision process or task that evolves from the interaction of the DM and the design team. The resulting DSS contain representations that are a compromise of the DM's requirements with the capabilities of the computer hardware and software that is available.(Martin 1984).

A key component of the Application Model is the level of management supported. In this respect the concepts of strategic, tactical and operational management as defined by Anthony(1965) can also be used as descriptive for a type of system.(Stair 1984)

Many authors have described the characteristics of DSS systems, often discussing the Application Model and the Systems Model together.

Stabell(1983) observed that to "secure an effective system for decision support" it is necessary that the predesign description and diagnosis of decision making be carried out prior to and as part of the DSS development. Design trade offs must be considered and appropriate structures determined. The trade off between modelling the current situation and presenting new representations is one such challenge.

Others have categorized DSSs based on types of

Application Models. Altar(1980) identified seven reasonably distinct types of decision support systems;

1. File drawer systems,
2. Data analysis systems,
3. Analysis information systems,
4. Accounting models,
5. Representational models, including simulation models,
6. Optimization models, and
7. Suggestion models.

Specifically, Altar(1980) discusses these as follows:

> "Representational models include all simulation models that are not primarily accounting definitions, i.e., models that use at least partially non-definitional relationships in estimating the consequences of various actions, environmental conditions, or relationships." (p.82)

Within this category Altar(1980) describes representational models as being:

"Type of Operation:	Estimating consequences of particular actions.
Type of Task:	Planning, budgeting.
User:	Staff Analyst.
Usage Pattern:	Input possible decision; receive estimated monetary or other results as output.
Time Frame:	Either periodic, as part of an ongoing process, or irregular, as a tool for ad hoc analysis." (p.84)

With respect to the Application Model, the question of **scope versus depth** of system capabilities led Stabell(1983) to emphasize scope over depth. He argues that this follows from a desire to keep the system simple but at the same time **usable and useful.** And he emphasizes that it is important to address the whole decision cycle for substantive and procedural learning reasons. He contends that it is seldom feasible to start with a system that does everything at once. In this case scope is given priority at the expense of depth when viewed as a long term objective for what necessarily needs to be an evolutionary system development process.

4.3.2.2. The DSS Systems Model

The characteristics of a DSS System model are derived from several viewpoints. As a commentary on methodology of developing decision support systems Alter(1980) identifies the **interface between decision support systems, operations research and management science (OR/MS) and information systems (IS).** In examining a DSS which supports the Tanker Investment Decision Process, he illustrates the different approaches used in OR/MS, information systems approach and decision support systems. With the emphasis on the "decision" the DSS would initially as a first system "provide functions for evaluating and comparing investment alternatives generated by the user". He further indicates:

> "Such a first system would not support problem-finding, alternative generation, or post-implementation evaluation. When we start describing how the system might be extended in subsequent versions, elements from the OR/MS approach and from the IS approach might be considered as a part of a balanced and coherent system architecture to support the whole process." (p.253)

Stabell(1983) describes components of the System Models through the use of evolving processes that use **more extensive and powerful tools.** To accomplish these, suggested features include:

1. presentation form for logical data structures,
2. system defaults,
3. differential ease of transition between different system functions, and
4. the structure of memory aids.

To achieve this approach Stabell(1983) recommends the following **system capabilities:**

1. Focus attention on the nature of the decision problem by differentiating between the control variables which define decision alternatives, non-controllable variables that the decision maker cannot control but that affect the desired decision outcomes or decision criteria.
2. Facilitate the evaluation of alternatives by providing user controlled report or scanning capabilities to facilitate comparison on the basis of multiple decision criteria.
3. Extend the planning horizon giving default definitions of variables as if they were time dependent to remind the decision maker of possible changes.
4. Support uncertainty exploration by allowing the simulation of consequences of differences in cause/effect and states of the environment.
5. Facilitate the integration of the user's

subjective estimates allowing him to modify a private copy of data inputs as well as other readily available and objective computer based data.

6. Facilitate learning by providing functions for recording and revisiting key decision assumptions. In this respect the results of certain decisions should be monitored and where possible indications reentered to indicate the quality of the decision based on the use of the DSS with a given set of variables and parameters.

Stabell(1983) identifies specific examples of the systems model in design features as:

1. The function for entry/display/alter of model inputs through a menu of items grouped according to distinction between controllable and non-controllable variables.
2. The illustration of non-controllable variables over a time period.
3. The pair wise comparison of alternatives providing a data structure composed of a working set and a reference set interchangeable and re-accessible.
4. A menu of system functions organized for the ease of navigation according to the phases of the decision process with "shallow" hierarchy of functions to expedite movement between them.

Carlson(1983) analyzed decision support systems with the following requirements identified:

"Decision making

1. There are a variety of decision making processes,

so a DSS should support multiple processes.
2. Different types of decisions have different data processing requirements, so a DSS needs to be flexible in order to support different types of decisions.

Decision Makers require support in the forms of:
1. Decision makers rely on conceptualizations in making a decision, and a DSS should provide familiar representations, (eg. charts and graphs) to assist in conceptualization.
2. Decision makers perform Intelligence, Design, and Choice activities while making a decision, so a DSS should provide operations which support these activities.
3. Decision makers need memory aids, so a DSS should provide memory aids which help carry out the decision making process.
4. Decision makers exhibit a variety of skills, styles, and knowledge, so a DSS should help decision makers work in their own idiosyncratic ways.
5. Decision makers expect to control their decision support, so a DSS should provide control aids which help decision makers exercise direct, personal control." (p.20)

The point is also made by Carlson(1983) that in situations of this nature when a solution is arrived at it is important that the system provides the decision maker with the information on justification needed to either convince himself or to support his decision to others.

In considering the design features of a decision support system Stabell(1983) reviewed general guidelines for the design of human-computer interfaces from studies conducted by Shneiderman (1980) and Cheriton (1976). In summarizing their work he states:

"If general guidelines are not followed such as keeping the interface simple, responsive, user-controlled, flexible, stable, protective, self documenting, and reliable are violated the system will most likely not be used. However, respecting such guidelines will not necessarily secure an effective system for decision support." (p.248)

To provide control aids Carlson(1983) suggests that the user interface incorporate:

1. menus or function keys for operation selection,
2. learning aids such as help commands,
3. training methods which allow a decision maker to learn by doing,
4. combining operations associated with one or more representations into procedures,
5. including construction of these procedures by the user,
6. the operations necessary for changing any DSS default values and
7. a facility for user specification of graph or label conventions in reporting.

In discussing user interfaces Carlson (1983) suggests the following alternatives:

- question and answer interfaces whereby the system queries the user one line at a time,
- command language interfaces where specific commands can be used,
- menu interfaces commonly used in today's on-line systems,
- input forms/output forms interface filling in the blanks and making check marks or selections,
- and various combinations in extensions of the above.

With respect to the design of their system, Keen and Gambo 1983) identify the importance of specific user verbs and their correspondence to system commands.

Systems are often described by the type of computer that they are operating on, for example, mainframe systems, mini systems, micro systems.(Martin 1984)

James Martin (1984) prescribes a future Utopian systems environment in which user developed systems using fourth generation languages, and highly productive system developers employing these powerful tools to develop systems around a centralized implementation of the organization's data model (data base architecture). In such an environment the availability of organizational data is implied through prior data modelling and data base creation projects. Systems residing on different processors (micros or minis) would be connected to the central data base system. Martin also envisages concepts of decentralized data base architectures as well. In this structured systems environment Martin supports concepts of prototyping, fast application development, quick modification, user developed systems, user/designer co-developed systems, interactive system design and development, and tight data administration.

In summary the foregoing design features are intended to support the overall decision process which usually includes:

1. identification of several decision alternatives,
2. the exploration of these alternatives,
3. the identification of uncertain elements or developments,
4. the assembling of information from a wide variety of sources and decision aids,
5. processing the appropriate models to execute these with the different alternatives and scenarios

considered and lastly,

6. to present in a user friendly reporting method the results of these different analyses.

In summary the systems model is composed of the sub technologies of:

1. User interface representations,including:
    1. Retrieval of information
    2. Display formatting options
    3. Data manipulation and summarization functions
    4. Trial testing simulation, or "what-if"capability.
    5. Reporting
    6. Model of portions of the decision environment.
    7. User interaction methods.eg keyboard, mouse, tablet, voice, etc.
2. Development language or system modelling tools
3. File management system
4. Specific terminal or workstation.

4.3.3. The DSS Success Profile

Decision Support Systems are a sub field of the broad field of Information Technology.(Stair 1984). The study of the factors that promote successful DSS can be divided into the following:

1. Information Technology Success factors
2. Specific DSS success factors.

4.3.3.1. Information Technology Success factors.

The literature is extensive on the factors that contribute to the success of Information Technologies. These factors have been divided into macro and micro organizational factors.(Gibson & Nolan 1974, Lucas 1979, Clowes 1979 and Cash, McFarlan & McKenny 1983). This review of the literature has resulted in these factors being grouped accordingly:

A. Information Technology Success Factors

I. Macro Factors

1. Issue driven New Technology Adaptation
2. Stage of Computerization
3. Technical staff.
4. Consistency with Strategic Directions
5. Basic Operational Measures of the organization
6. Organizational position of the Information Technology function .

Table 4.1 illustrate the Outlines of the Macro organizational factors reviewed. Many of these factors have been included in the CDO.

Table 4.1
Macro Organizational Factors

Author: Huff and Munro (1985)

1. Technology is adapted into organizations in a manner described by the Information Technology Adaptation Assessment model, ie. technology vs issue driven.
2. The ITAA model identifies six interest groups involved in the ITAA process.
3. New technologies that are implemented as a result of both critical need and the availability of the new technology are most successful.
4. The greater the involvement of users and senior management the more likely the success of the application

ITAA Phases and Processes (Huff & Munro, 1985)
MODEL OF TECHNOLOGY ADAPTATION: Need vs Technology
For the evaluation of major applications,ie: new technologies

TECHNOLOGY:	NEED: VERY IMPORTANT	NEED: NOT CRITICAL
AVAILABLE	Normative Ideal	Technology Driven
UNAVAILABLE	Issue Driven	Opportunistic

MODEL OF TECHNOLOGY ADOPTION AND INTEREST GROUPS:

I PHASES:(How did each application move from phase to phase?)

1. AWARENESS
2. INTEREST
3. EVALUATION
4. TRIAL
5. IMPLEMENTATION
6. DIFFUSION

II. INTEREST GROUPS:(Who played each role, for each application?)

1. USERS
2. INFLUENCER
3. DECIDERS
4. GATEKEEPERS
5. PLANNERS
6. SPONSORS

Table 4.1 continued

Author: Gibson and Nolan (1974), Nolan(1979)

1. Four distinct stages of computerization growth are: Initiation, Expansion, Formalization and Maturity.
   Organizations in the Expansion Stage are most likely to accept new technologies.
2. Adequate specialized technical personnel are required to implement new applications.
3. Management techniques ensuring that Information technologies are directed towards strategic directions are required. This usually is achieved by significant involvement of senior management in the direction and monitoring of the information function.

Author: King and Kraemer (1984)

1. Stages related to Nolan(1979) are:
   - INITIATION (as described in both),
   - EXPANSION (Nolan 1979) as compared to Contagion (King and Kraemer 1984),
   - FORMALIZATION as described by Nolan appears to overlay with Contagion, Control and Integration, and - Data Administration as described by King and Kraemer. - MATURITY, similar contexts.
2. Each stage has a different composition of technical staff.
3. An organization in the stage of Contagion, Control or Integration is positioned to implement new applications.

STAGE:
I.INITIATION
II.EXPANSION i.e.a.Growth of applications, Personnel Specialization, and Mngt Techniques
III.FORMALIZATION, Subdivided by King and Kraemer(1984) into
1. Contagion,
2. Control and Integration, and
3. Data Administration
IV.MATURITY

Table 4.1 continued

Author: Ein-Dor and Segev(1978)

1. Operational Measures effecting application success can be grouped into uncontrollable, partially controllable and controllable.
2. Project success is more likely if the Operational Measures rate high. These Measures are:

Uncontrollable

1. Annual sales, workforce, assets, market share
2. Number of products, market units, profit centres, divisions & groups
3. Planning horizon, length of strategic decision process, rate of technological change in industry
4. Availability of trained manpower, hardware, software, decision techniques

Partially Controllable

5. Size of Budget, Liquidity
6. Degree of system formalization, level of quantification, availability of decision relevant data
7. Attitudes to information systems, perceptions of systems, expectations

Controllable

8. Number of levels below chief exec.
9. Identification with functional level
10. Steering Committee existence; organizational level

II. Micro Organizational Factors

While Macro indicators of success are important, as Montazemi (1986) states in his evaluation, the true measure of success of information systems must be based on a more tangible measurement.

Several authors have conducted empirical research to establish a number of criteria which can be linked to successful computerization or to unsuccessful computerization. (Lucas, 1975; Clowes, 1979; Bailey & Pearson, 1983) These researchers and many others conducted important work towards identifying those attributes of a project and a computer systems organization that when present contributed to more effective use of computers in an organization. Others such as Raymond (1985) and Montazemi (1986), identified that smaller organizations have slightly different characteristics for successful computerization than prior research which appeared to focus on large organizations.

In a study conducted by Montazemi (1986) he determined that identification of success itself is complex and many faceted:

> "It is difficult even to formulate any complete definition of successful performance of an information system, much less to develop a measure that adequately represents it. This adds another dimension to the facility of prematurely postulating stated hypothesis in regard to success or failure of information systems in small businesses." (p. 45)

The study conducted by Montazemi obtained results relating user satisfaction factors to characteristics of the systems developed and implemented, and the hardware and software used in the systems. The relevance of Montazemi's study to this research is that it identifies the important factors in the definition of success and relates these to end user satisfaction. From the viewpoint of the research goals of this thesis, these factors provide a means of identifying success factors for future scheduling systems and are seen as a means of describing and comparing the three cases studied. The factors identified as important in user satisfaction by Montazami(1986) are presented in Figure 4.2

Table 4.2
User Satisfaction Factors(Montazami 1986)

A. Importance Scale by Factor in Descending Order of Importance

Extremely Important
High Satisfaction

1. Top Management Involvement - initiation, participation and emphasis,
2. Communication with EDP staff
3. Convenience of Access - user has dedicated system
4. Perceived utility- could not be done otherwise
5. Confidence in system - proven usefulness
6. Feeling of Participation - from design to user control
7 Processing of change requests - very good for minor changes
8. Vendor support
9. Documentation
10. Format of output
11. Currency.e. information is current

Low Satisfaction

1. Priorities determination - problem with subsequent allocation of EDP staff
2. Timeliness - weekly cycle requires constant daily input of changes
3. Reliability - due to estimated inputs
4. Accuracy - due to estimated inputs
5. Integration of system - most inputs should be communicated from main computer system
6. Processing of change requests - slow for major enhancements
7. Processing of change requests - magnitude of change is not considered
8. Means of input/output with EDP centre - does not consider that user may run own system on a micro dedicated to their system

4.3.3.2. Specific DSS Success Factors

These specific DSS success factors have been defined by the practice of system researchers and developers. These factors have been reported on extensively and include the following.

Boritz(1990) analyzed the works of several DSS researchers and concluded that success was determined by the extent that the system provided information that was:

1. Relevant-the right information,
2. Available at the right time,
3. Appropriate level of detail for the decision,
4. Justifiable - information presented for the right reasons,
5. Accessible- flexible access of retrieval
6. Efficient- small user work space for user and system,
7. Comprehensive-complete in an acceptable format,
8. Salient- focus on important information.
9. Usable-ease of user interface.

Boritz(1990) also identified potential reasons for failure, including:

1. Resource constraints to users involvement,
2. User motivation to use or mis-use a DSS,
3. Organizational and environmental requirements and constraints.

In the "information centre" concept, from the time a project begins with the user, the initial period of time for user training and initial system endeavours can be lengthy depending on the time allotted to the exercise by the user department. In addition, the quality of the resulting systems is seen to be dependent upon the expertise involved at a technical and user level. Without the technical expertise present, the resulting systems may not be adequate or not as comprehensive as those developed with technical assistance. In addition, with less technical assistance elapsed development time of a system could be expected to be longer due to the users' low technical expertise and their inherent "learning curve"(Martin 1984).

One measure of a DSS success is in achieving the end objective of reducing the applications backlog(Martin 1984). This can be promoted through the DSS prototyping approach, even with detailed systems expertise involvement in projects. The key in this objective is to give the systems designer the most leveraged tools available, such as fourth generation languages including LOTUS to facilitate rapid prototyping to the point where a significant system can be developed to aid the end user problem solution.

Kranshaar & Shirland (1985) emphasize the justification for rapid prototyping as being a means to improve the productivity of systems development efforts. To achieve this they propose:

> "This can be accomplished by either developing systems more quickly, or by providing proper development guidelines and assistance so that functional areas can develop their own application systems with minimal IS(Information Systems) department resources." (p.189)

Keen and Gambino (1983) recognized the following success factors:

1. that the skills of the designer and, in their

project, the APL programmer, must be above the average data processing professional.

2. the importance of a close designer/user relationship. They identify the need for "hand holding" not because users are stupid or afraid of the system but because the adaptive links consistently strain the existing system. Further they identify this process as follows:

   "We found that personalized usage is, as we expected, the rule and not the exception." (p.158)

Summary:

It follows that the DSS system being designed and developed in a close user/designer team does reflect the personal cognitive style of the user. And thus to accurately implement mechanisms appropriate for that user's style the ability to quickly test, implement and refine suggestions are supportative to develop a usable system in a short period of time. There is a relationship between the fourth generation language utilized and the methodology for developing successive prototypes. The relationship, however, is made more complex by considering not only the language system, but also the designer/programmer resource(s) used. Specifically the relationship appears to be the net result of the combination of:

a) a better "rapid prototyping language" (such as LOTUS)

b) a highly skilled designer and programmer team (the ideal being a single designer/programmer).

The development environment described above is an efficient and effective development process which tends to merge the traditional analysis-design-development-testing cycle into one step rather than individually recognizable steps.

4.4. EXPERT SYSTEMS

4.4.1. Expert Systems Background

Although the initial concepts of artificial intelligence(AI) were studied in the mid 1960's, it was not until the 1980's that extensive research and commercialization began(Barr & Feigenbaum 1981, Feigenbaum et al 1988, Hayes-Roth F., Waterman D.A., Lenat D.B. 1983). The sub-field of study with AI that deals with the representation of human thought in systems technology is called Expert Systems, Knowledge Based Systems, or Intelligent Systems. For purposes of this discussion the term Expert Systems(ES) will be used.

Within the field of Information Technology, the ES field has been advanced from initial computer languages such as LISP and Prolog to dozens of AI shells that attempt to simplify or enhance the creation process of usable expert systems(Schoen & Sykes 1988). From a hardware viewpoint, simple ES's operate on micro computers, while more complex systems require dedicated workstations with large internal memory, disk storage and very fast processors.

In relations to DSS and MIS systems, ES applications are of two types:

1. Integrated with MIS systems, or
2. Stand-alone.

When integrated the type of integration is usually that of stored information sharing. When operating as a stand alone application the user supplies all the data or information as input.(Schoen & Sykes 1988)

ES applications exist in many areas were neither DSS nor MIS applications exist, such as medical diagnosis, and geological exploration(Hayes-Roth et al 1983). There are however, many applications in organizations that have been extensive users of MIS and DSS technologies(O'Farrell 1986). In these latter organizations the ES applications fill a need that either could not be addressed adequately by MIS or DSS, or where ES technology provides an enhanced solution.

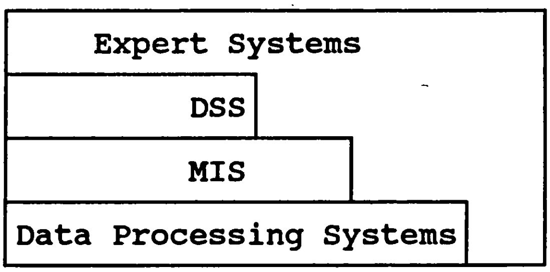
In summary ES applications can be represented as:

1. New systems,
2. Enhancements for DSS or MIS systems
3. Replacements for inadequate DSS or MIS systems.

This positioning is represented in Figure 4.3.

Figure 4.3

System Relationships



One of the deficiencies of MIS and DSS systems in manufacturing applications is expressed by Vernadat (1987),

> "Information management and processing is at the heart of CIM(Computer Integrated Manufacturing) technology. Unfortunately, the complete automation of the product life cycle using current data base technology assumes that:
> 1. Everything in manufacturing is deterministic (i.e., conventional computer programs can be written),
> 2. Any situation can be dealt with by the programs, and
> 3. The input or stored data are always accurate.

Obviously these conditions are not realistic in the manufacturing world which involves exact but also stochastic, fuzzy, vague, or incomplete information, complex decision-making, and for which many algorithms are not yet completely established."

Many researchers believe some of these limitations can be overcome using ES technology. With respect to the general scheduling problem, Fox(1983) was one of the early researchers. Since his initial work many others have begun to view ES as having the potential to solve these difficult problems(Kusiak 1987, Newman 1987)

The discussion on Expert Systems follows the general form of the DSS discussion, namely, Paradigm, Methodology, System Model and Success Profile. Where relevant the concepts related to Expert Scheduling Systems are compared to the general ES viewpoint.

4.4.2. The Expert Systems Paradigm

In this discussion the ES paradigm is described in two forms, namely;

1. The general Expert Systems Paradigm, and
2. The specific interpretation as applied to Expert Scheduling Systems.

4.4.2.1. The General Expert Systems Paradigm:

A useful view for the ES paradigm is to compare it to those of MIS and DSS systems. While MIS systems present information to managers, and DSS systems provide tools to assist in the decision making process, ES systems attempt to actually replicate the thinking processes of the expert decision maker(Stair 1984, Hayes-Roth 1983). In this respect, the ES paradigm is an evolution beyond the providing of information and the assistance of the decision making activities.

The fundamental concept of an expert system has been defined by Barr and Feigenbaum (1981) as:

> "...an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for there solution."

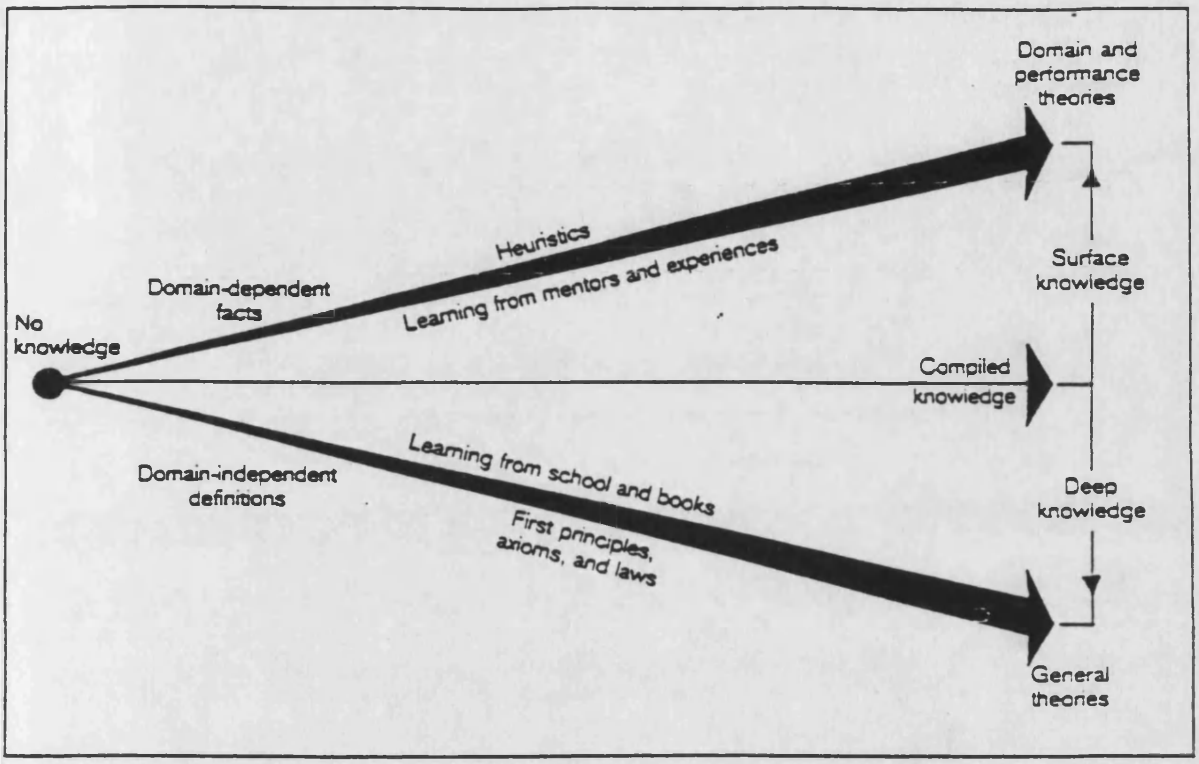
The essential elements of an ES are:

1. The existence of an expert,
2. The capturing of the inherent expertise in a knowledge base, and
3. The representation of the expertise in a system, called an Expert System.(Harmon & King 1985)

Each of these essential elements has significant implications and challenges for researchers. The notion of an expert, and expertise have been studied by Harmon & King (1985). One of the characteristics of experts is that they are linked to one clearly defined domain or body of knowledge.

Experts are experts because they have a large amount of compiled, domain specific knowledge stored in their "long term memory". The nature of the memory of a human is seen to be such that information is stored as "chunks" which can be retrieved, examined and utilized at will. Psychologists are said to believe that it takes at least 10 years to acquire 50,000 chunks of information. This suggests that it takes 10 years of study and practice before a individual can become an expert and that between 50,000 and 100,000 chunks of heuristic information is required. Harmon and King(1985) indicate their belief that most experts become so, initially, by studying the formal knowledge in educational institutions and, subsequently, refine that knowledge through practical experience. As a result of the practical experience experts are seen to rely primarily on "surface knowledge" which includes heuristics. Only when unusual or complex problems are presented will an expert rely on first principles and general theories. These underlying principles and theories are termed "deep knowledge". Within the field of expert systems the relationship between the two types of knowledge have led to the formation of two system descriptors. Those systems which contain and represent surface knowledge only have become known as "expert systems", while systems which embody additional "deep knowledge" have become known as "knowledged based systems". (Wiederhold 1985). Figure 4.4 illustrates a viewpoint of knowledge.

FIGURE 4.4 - VARIETIES OF KNOWLEDGE
(From Harmon and King, 1985)



4.4.2.2. The Expert Scheduling System(ESS) Paradigm:

The identification of this discipline or, field of endeavour, as relating to "significant human expertise" and practitioner knowledge suggests that the scheduling problem may lend itself to solution through the techniques of this discipline.

The essential elements of an Expert Scheduling System would be:

1. The existence of a scheduling expert,
2. The capturing of the inherent scheduling expertise in a knowledge base, and
3. The representation of the scheduling expertise in an Expert Scheduling System.

Fox(1986) observed that the existence of an expert scheduler is not confirmed, since the process of creating a schedule is a combinatorial decision making activity with rapid change, few normal states, and is primarily a process of reactive management. As such the existence of an expert may be in doubt, because the nature of the scheduling problem is so difficult.

4.4.3. The Designing of Expert Systems

4.4.3.1. General ES Methodology

The accepted methodology for designing expert systems prescribes the following processes:(Hayes-Roth 1983, Harmon and King 1985, Schoen & Sykes 1988)

1. Identification of a specific domain of interest, with a problem worth solving.
2. Identification of an expert or source of

expertise, that can be studied,

3. Identification of an individual or team that can study the domain, and the expert's performance and conduct in operation. These individuals are called "knowledge engineers"(KE).
4. Analysis of the expert by the knowledge engineer(s) to identify the nature of the expertise or knowledge and to document it. This process is called "knowledge acquisition".
5. The representation of the expert's knowledge or expertise in a form that is, or will become, part of an eventual system. This process is called "knowledge representation".
6. The selection of a hardware and software environment that facilitates both:
   a. the representation of the knowledge and the use of the resulting system by the expert and/or other users, and,
   b. the process of prototyping or evolutionary development.
7. The conduct of a development project, involving the expert and the KE's, using prototyping or iterative development cycles, to build a system that performs like the expert does.
8. The conclusion of an experts systems development project is far more difficult to identify, since many projects begin with differing goals, such as:
   a. Develop a demonstration system,
   b. Conduct a "proof of concept" project,

c. Create a prototype of an eventual delivery system.

d. Create version 1 of a productive system.(O'Farrell 1986, Schoen & Sykes 1988),

9. The cut-off or end of a project occurs when;

a. The budget is exhausted,

b. The "proof of concept" is proven, or disproved.

c. The prototype is determined to be sufficient to create a delivery system.

e. Version "n" is determined to be adequate or inadequate, and

f. Another approach is determined to be more promising.

The task of knowledge acquisition has been studied by Vitalari(1985). This study reviews the knowledge categories (KC) and differentiation between these KC's by novices and experts in the "Systems Analysis" field. Another study by Schvanveldt R.W., Durso P.T., Goldsmith T.E., Breen T.J., Cooke N.M., Tucker R.G., DeMaio J.C. (1985) reviews concepts and the "interrelationships" employed by fighter pilots in the U.S. Air Force.

Examples of successful experts systems that have followed this methodology are:

1. MYCIN, to diagnose meningitis and other bacterial infections of the blood stream, developed the Stanford Medical School(Hayes-Roth et al. 1983),

2. XCON/XSEL, to configure computer systems, developed by McDermott(1982) for Digital Equipment

Corporation.(Hayes-Roth et al. 1983)

3. Prospector, to assist in the exploration for mineral deposits(Hayes-Roth et al. 1983).

Gaines (1987) identifies the requirements of knowledge support systems and refers to systems such as PLANET as reported upon by Shaw in 1980, 1982, 1986 which begin to develop this concept of knowledge support systems. Further the system TEIRESIAS as an extension to MYCIN is also an early form of knowledge support system.

4.4.3.2. Expert Scheduling System Methodology

A review of attempts to develop expert scheduling systems is far less conclusive. A significant portion of the research discusses concepts and prescribed approaches rather than proven methods resulting from extensive case studies.

Steffen(1986)identifies the rapid growth of AI Scheduling research, but concludes that most work is in the research stage and there are very few practical applications. He does identify that there could be many internal company projects that may not be reported for some time.

The scheduling domain is a subset of the manufacturing domain. As such the growth of manufacturing systems technologies is relevant. The evolution of systems in the manufacturing world has passed through many stages including:

1. Bills of material-inventory control-work in

process,

2. Sales forecasting/order processing,
3. Material requirements planning-MRP,
4. Capacity planning,
5. Production planning/scheduling/control,
6. Production control-shop floor and data acquisition systems,
7. Design-engineering systems,
8. Design-CAD/CAM systems,
9. Manufacturing requirements planning-MRP-II,
10. Just-In-Time. (Peterson, 1988)

Vernadat(1987) cites new developments with classifications of;

1. Computer Integrated Manufacturing(CIM),
2. Factory of the future.
3. Intelligent manufacturing systems.

To Vernadat (1987) the factory of the future is synonymous with CIM and means the "complete integration of the many computerized activities of CAD, CIM, and production management (PM) through group technology (GT) principles by means of a common information system".

As a further comment the author states that "CIM is an evolving concept and not a technology".

Considering the eventual development of expert systems in the CIM evolution the author states that:

"Cooperative expert systems: Decision making in production management will undoubtedly make use of several expert systems which will have to communicate and cooperate. For example, a MRP expert system may need information from the capacity planning expert system before producing its output. Blackboard architectures have been proposed to deal with this kind of situation."

In addition the author identifies that multiple knowledge base representations will be required as will forward and backward chaining if not additional hybrid representations. Further integration including knowledge sharing, in which the same knowledge rules may be applied to various application fields, may exist. Knowledge must be kept in common knowledge bases and shared by various expert systems in a way similar to data sharing in data bases. He further identifies structured methodologies for structuring the knowledge base and designing inference control structures are needed.

Before substantial progress can be made Vernadat(1987) states:

> "However, further progress has to be made in the following directions:
> - elaboration of more adequate data models and knowledge representation schemes
> - refinement of new data base design methodologies based on semantic data models
> - refinement of expert system design methodologies
> - development of integrated KBMs (knowledge base modules) for engineering and manufacturing requirements
> - building CIM systems structured around engineering information systems (EIS) and engineering and manufacturing information systems (EMIS)."

Research in the general field of experts systems in manufacturing has been carried out by authors such as Gaines (1987), Yu (1986), Kusiak (1987) who focus upon the various viewpoints of setting up flexible production lines and managing these. The excellent work conducted by McDermott et. al. (1982) in the development of XCON and XSEL addresses the specification and process planning for the manufacturing of DEC computers.

Bourne and Fox (1984) identify the chaotic world of the scheduler and since 1980 have developed expert scheduling systems using heuristic problem solving techniques based on constraints and their relaxation. Systems such as XSEL, XCON, ISIS, PDS, and INET have been developed by Fox (1986) and others towards the solution of production planning and scheduling problems in rigid manufacturing environments.

Fox(1986) divides AI research into the categories of : knowledge representation and search. Steffan(1986) identified 8 methods described by AI scheduling researchers:

1. Rule Based, used in unstructured problems but often replaced in scheduling applications as suitable structures are defined.
2. Heuristic Search, used to exploit the structure of a problem.
3. Constraint Directed Search, used when natural problem constraints reduce the size of acceptable solutions.
4. Frame Based, is an alternative to Rule based representations.
5. Hierarchial, used to decompose large problems into more manageable ones, with the risk that sub problems require interaction.
6. Distributed, is a the application of coordinated

parallel processing to decomposed sub problems.

7. Interactive,, used in almost all systems to varying degrees, and,
8. Temporal Reasoning, used to represent time related reasoning.

Kusiak and Villa(1987) group development methodologies into the categories of:

1. Hierarchial, as in #5 above.
2. Non-Hierarchial, in contract to Hierarchial.
3. Script-based, using predefined data, knowledge and solution structures.
4. Opportunistic, using an interactive blackboard with the scheduler making solution suggestions.
5. Constraint Directed, using heuristic search techniques with constraints guiding and bounding the search space.

Several of Steffen's(1986) general conclusions are relevant to this study, namely;

1. Rules-of-thumb from good schedulers were often imbedded in an ESS.
2. An ESS often included methods of analysis that were beyond schedulers methods due to inability to deal with complexity and size of problem, limited strategy, inaccurate levels of abstraction, crisis reaction, and dynamics of change.
3. A problem that appeared to be unstructured, may be an indication of poor design.
4. More research is needed in the integration of scheduling with MRP.

5. The goal should be to solve an organization's needs.
6. There is a shortage of people with experience in manufacturing and AI that are capable of implementing working systems.
7. Future scheduling systems will be integrated with MRP, MIS, and CIM strategies.
8. Systems will be developed by incremental evolution in complexity and decision making

Cantaluppi et. al. (1984) suggest that solutions in the future require the integration of management science methods, computer technology and a deep integration of the planner and scheduler through sophisticated man machine dialogues.

Nassr et. al. (1985) have produced a "flexible automated manufacturing system (FAMS)" to plan, schedule, simulate and control production in small to medium size manufacturing environments.

4.4.4. Design Representations of Expert Systems

4.4.4.1. General ES Design Representations

The design representations found in expert systems have been categorized into the following;

1. User Interface(Harmon & King 1985, Gaines 1987)
    a. natural language processing,
    b. graphical images and icons to represent domain objects
    c. mouse or similar hand operated control device,

  d. multiple display windows and types presented simultaneously,
  e. solution status indicators.
2. Inference Engine, to reason or solve the problem
3. Knowledge Representations or knowledge Bases, to represent the knowledge,
4. Reasoning Explanation, to explain the process the system used to reach its decision or conclusion.
5. System enhancement by machine learning or knowledge enhancement.
6. User sensitive expertise levels, to provide guidance for a novice user, and varying degrees of expediency for expert users.(Gaines, 1987)

Many variations and combinations of the above can be found in documented expert systems.

4.4.4.2. Expert Scheduling System Representations

In the scheduling system research there are very dew reported working systems(Steffan 1986). Consequently specific design representations reviewed do not reflect the same breadth of accepted wisdom as the review on decision support systems. The systems that were studied are reported upon accordingly.

Nassr et. al. (1985) have produced a "flexible automated manufacturing system (FAMS)" to plan, schedule, simulate and control production in small to medium size manufacturing environments. The emphasis is placed on the scheduling and modelling functions with a discreet event simulation being used to produce the schedule and the simulation modelling capability utilized to test variations of the system. The design representations of the System Models and the Application Model(the Scheduling Model) are summarized in Appendix B4.

One of the major projects which Fox(1986) has devoted considerable time to is the development of an expert system entitled ISIS III. Specifically, the sub-functions that ISIS addresses as identified by Fox(1986) are:

1. Production planning- the selection and sequencing of operations to manufacture a product
2. Production Scheduling, selecting a process routing, resources and operation times.
3. Resource planning, determining quantities and times for resources
4. Monitoring and control, detection and correction of manufacturing problems.

Clearly, the ISIS scope is seen as being involved with all the functions related to the selection, sequencing of operations for manufacturing, including in detail the machine and operation routings and the identification of required resource quantities and types in the assignment of timing to all these factors. Within the resource planning function, Fox identifies that ISIS is seen to perform functions within the general manufacturing requirements planning or MRP II environment.

In defining the architecture of ISIS III, Fox illustrates the system as being composed two components; namely, knowledge representation and scheduling.

The importance of monitoring and control to detect manufacturing problems is fundamental to the ISIS system. Because the system schedules activities within a daily time frame, production delays must be represented as a feedback mechanism to the system. Upon receipt of feedback information, the scheduling system must reschedule the appropriate activities.

Tracing its evolution ISIS was described by Borne and Fox (1984) as follows:

"The ISIS system is an artificial intelligence, constraint-directed reasoning system which addresses the problem of how to construct accurate, timely, realizable schedules and manage their use in job-shop environments."

The initial manufacturing problem that ISIS was applied to was one of the processing of a shop order or series of orders through a heavy metal industrial setting including the utilization of robotics and other semi-automated NC machinery. The authors summarize the importance of ISIS in the evolution of expert systems as being:

> "A contribution ISIS makes to the job-shop planning and scheduling problem is its focus on representation, utilization, and relaxation of constraints in the scheduling process. ISIS's knowledge representation language, SRL-2 can represent an extensive set of constraints and their relaxations. Categories of constraints which ISIS covers include organizational goals (for example, due dates, cost, quality), preferences(for example, for machines), enabling states (for example, resources, previous operations), physical characteristics (for example, accuracy, size), and availability (for example, existing reservations for tools). ISIS uses a constraint-directed search paradigm to solve a scheduling problem. (Borne and Fox 1984)."

In the above situation, ISIS was applied to a turbine components manufacturing process. In this environment, Fox identified that the orders have lead times of as much as three years, although spare parts are also required on a same day basis.

Emphasizing the importance of constraints in problem solving in the scheduling environment, Fox (1986) identifies the following observations:

"1. Constraints define the parameters of states in the search space.
2. Constraints define single state general operators
3. Constraints define situation or condition of an operator.
4. Complex operators are the combination of two or more constraints.
5. Constraints define the evaluation function
6. Levels of representation are defined by constrained variables part-of hierarchies
7. Levels of search are defined by the importance of a constraint
8. Levels of search are defined by the elasticity of a constraint
9. Levels of search are defined by constraint interactions
10. Constraints focus attention on islands of certainty
11. Constraints direct the diagnosis and repair of poor search decisions." (pp.184-185)

As a pioneer in the application of knowledge engineering techniques to the production scheduling, the work of Fox(1986) is of fundamental importance to this or any other research involved with future scheduling and manufacturing related expert systems.

While few working systems exist, several researchers have studied the question of design and have suggested several design concepts and architectures. These are described below.

Kusiak and Villa(1987) visualize a tandem architecture embodying traditional scheduling solution models including,

1. Simulation,

2. Analytical,

3. Mathematical programming.

A controlling expert system identifies the type of problem and performs the functions of:

1. Data Reduction,
2. Parameter generation,
3. Constraint generation,
4. Solution generation,
5. Solution evaluation,
6. Any combination of the above.

Such systems could be goal based or model based.

At the same time as information processing and integration has been automated, the complexity and uncertainty of most modern production environments have not been completely resolved by current scheduling techniques. Newman(1987) identifies that:

> "The approaches used in most situations (scheduling) are not only inefficient but also fragile when confronted with unexpected events. In addition, segregation of scheduling activities from other production planning and control tasks is difficult due to the complexity of data requirements, information dependencies between the business and production units, variations in manufacturing contexts, and the cascading effects of schedule execution." (P.3)

Newman(1987) identifies that scheduling activities fall within the domain of production planning and control which include process planning, operation scheduling, and shop floor control. The difficulty in defining precise characteristics and boundaries of these functions is identified as severe because of their complexity and variations in organizational preferences. Addressing the semantics of production planning, scheduling and control the author suggests that the activities are related. In this respect, scheduling is seen as part of the production planning and control functions. Scheduling is seen as ranging from long range projections to detailed task scheduling. In recent MRP II evolution the importance of a "master schedule" has been identified. The use of master schedules is discussed in differing terms, although for the most part, the master schedule can be identified as follows:

> "Long-term scheduling provides the necessary coordination of activities for multiple function areas. . . . The output of this function is a plan for the overall level production sometimes referred to as the master schedule. It typically involves time periods of months, weeks, or days. The master schedule represents the overall manufacturing program to which all the subsequent detailed planning and scheduling will be geared. It ensures that production schedules are feasible and that the detailed plans which evolve from them can be executed. The contents of the master schedule serve directly or indirectly as a guide for not only the total capacity demand, but the final production priorities as well. It is used by management to determine the need for new equipment acquisition, labour requirements involving changes, cash flow needs, predicted effect of seasonal changes upon production, and possibly, the need for policy changes. The master schedule is also the basis for such activities as detailed scheduling, inventory management action, procurement action, and manufacturing action." (Newman 1987).

Short term scheduling is seen as controlling resources and their assignment and times in periods measured within days or less. Short term scheduling is carried out with the objectives of achieving delivery dates, minimizing in process inventories, maximizing machine and labour resource utilization. Identifying the information required for short term scheduling, Newman(1987) identifies:

> "The scheduler who produces the short-term schedule will require much of the same information as that used for input to the long term scheduling task. Additional detailed information is also necessary. The most important information is contained in the bill of materials, followed by routing information which includes set up times, cycle times, and machine assignments."

Reviewing the pervasive nature of scheduling, Newman(1987)identifies:

> "The manufacturing strategy and environment effect the structure and flexibility of detailed shop-floor schedules. The precise definition of scheduling, the degree of complexity, and the usefulness and efficiency of automated schedulers will vary from one type of production environment to another."

4.4.4.3. Proposed ES Scheduling Methods

Newman(1987) identifies that current scheduling methods can be grouped into:

1. backward scheduling beginning with the due date of an order and working backwards identifying schedule dates, times and operations or groups of operations allowing for the required activities and the appropriate time spans for each such operation and activity.
2. forward scheduling proceeding from a start date and using scheduling rules and operations/activity times arriving at a completion or due date.

The author also identifies the scheduling can be done in a static mode prior to execution, a dynamic mode during execution, or a combination of the two. The difficulty with the dynamic or real time scheduling is the lack of foresight in making assignments of jobs to resources. Various approaches to the production or preparation of schedules and sequencing are identified as operations research techniques, simulation, network methods, combinatorial procedures and heuristic approaches. The author identifies that:

> "To overcome the difficulties associated with these approaches, it is necessary to create a scheduler that will allow decision coherency according to global objectives and, at the same time, have a sufficient degree of decision flexibility."

Identifying specific scheduling methods, Newman(1987) suggests the following:

1. The GANTT time progress chart - amenable to small schedules, useful for medium to large size problems.
2. Critical Path (CPM) or Project Evaluation and Review Techniques (PERT) - refinements of the GANTT charts, good for showing the interaction of the precedent relationships of activities.
3. Manufacturing Resource Planning (MRP) - providing for order analysis, inventory analysis, and processing schedules utilizing the master schedule and yielding a production plan. Such systems are seen to be highly computer intensive and rely on a high degree of accuracy in the computer data base.
4. Manufacturing Resource Planning (MRP II) - which, as well as identifying material requirements, integrates additional financial and production information. This method suffers from the same problems as MRP.
5. Simulation which allows the evaluation of alternate scheduling strategies and equipment and facility layouts. The disadvantages are considerable when viewed from a scheduling perspective. Not the least of which, is the need to rerun simulation runs in order to attempt to find a near optimum or "better" configuration or plan than the previous run.

6. Dispatching which addresses the problem of job priorities when several activities or orders are competing for the same resources. Many of the dispatching algorithms or rules are identified in the prior section on production/operations management.
7. Job sequencing which attempts to sequence the activities according to some defined objective function, i.e. minimum tardiness, minimum makespan, etc. Several sequencing algorithms and approaches were identified in the prior section on operations research methods.

Regardless of the type of method used, it is clear from extensive prior research by numerous authors that the difficulties of preparing sequences and schedules are many. Not only is the problem of the scope of the environment, which must be considered a challenge, but also the number of distinct time function assignments that must be made are vast. Clearly, research such as that conducted by Fox(1986) and others illustrates the need for the use of heuristics in an attempt to reduce the vast number of possible combinations to those which can be effectively computed in a reasonable period of time.

4.4.4.4. Requirements of a Good Scheduling System

. Newman(1987) and Fox(1986) identify a number of characteristics which are required of a good scheduling system. Such a schedule or scheduler process could be seen to satisfy the following requirements:

1. Satisfy all constraints.
2. Be robust enough to handle exceptions.
3. Be efficient in terms of meeting due dates and production costs.
4. Carry each product order through an appropriate sequence of operations from input materials or components to completion of the final product.
5. Meet the guidelines established through the organizational goals such as meeting due dates, minimizing work in process time, and maintaining production levels.
6. Allocate scarce resources between different competing jobs.
7. Anticipate unplanned interruptions.
8. Reschedule when necessary as required by changing events.
9. Use current conditions, i.e. feedback information as it is made available.
10. Include scheduling preferences as determined by senior management and historical practices and procedures.

4.4.5. Joint DSS - ESS System Directions

Several authors have reported research and a few working systems that portend to combine DSS and Expert Systems technologies(Martin 1984, Gory and Krumland 1983, Turban and Watkins 1986). These and the authors cited below identify the potential relationships between DSS and ES accordingly:

1. ES as a model manager for DSS tools,
2. ES as a guide and assistant to the use of the DSS,
3. ES technology deeply embedded into the DSS to guide the solution or model execution.

Alter(1980) and others cited the integration of DSS technology and MS/OR models and methods as an enhancement to a DSS. This is an easy integration to visualize through Boritz's(1990) model:

Data + Models = Decision Support System

The "Models" can quite easily be MS/OR models.

Bonczek, Holsapple and Whinston(1981) suggest that, to the extent that decision making is problem solving, the knowledge of a skilled manager or expert in a given domain, further enhances the DSS power. The new relationship then becomes:

Data + Models + Knowledge = Knowledge-based DSS(KBDSS)

or

DSS + Knowledge = KBDSS

The nature of the Knowledge representation in the DSS would be the combination of the facts of the domain and the Rules of Thumb employed by the expert. This would be accomplished by using ES technology.

Dutta and Basu(1984) explored the concept of using an Expert System to **manage the models in DSS** systems. The ES represented the DSS expert's ability to determine which DSS model/method to use to solve a series of different problems.

Kriwaczek(1982) developed a Prolog based outer shell for **guiding the user** in the operation of a DSS. Remus and Kottemann(1986) created an Intelligent shell that guided and validated the required conditions or the use of a Statistical Tools DSS.

Cooper(1986) saw an easy integration of ES into MS/OR, while Kusiak(1987) employed ES rules embedded into an OR based application for Flexible Manufacturing System(FMS) control.

In the area of DSS and ES integration in Scheduling systems, a few researchers have suggested guidelines for the development of such systems.(Kusiak 1986, Newman 1987)

Newman (1987) identifies that:

> "An approach to scheduling that will produce a usable schedule that is both robust and efficient, is to build real-time knowledge-based process schedulers using artificial intelligence techniques combined with some aspect of current scheduling approaches, i.e. dispatch, draft sequencing, heuristics, and simulation."

Identifying the types of knowledge which such knowledge-based systems would contain, Newman(1987) refers to Smith's(1986) work. The types of knowledge are:

1. Temporal knowledge, both absolute and relative,
2. Meta-level knowledge about the means of conducting appropriate searches, etc.,
3. Goals,
4. Available resources,
5. Possible actions,
6. Constraints, and
7. Preferences.

In addition, specific data potentially accessible from other modules in the CIM architecture include:

1. Due dates,
2. Priority designation,
3. Certain consumer data,
4. Product data,
5. Process information,
6. Preferences of consumers for specific processors,
7. Initial conditions, and
8. The matrix of sequencing constraints.

In addition to the foregoing Newman(1987) emphasizes key system representations:

1. Global knowledge base containing static information for general manufacturing and scheduling
2. Current world model containing the dynamic information which could be accessible from other systems or users.
3. Combined predictive approaches, reactive approaches, and related heuristics.
4. Representation methods including sets of procedures, semantic networks, frames, scripts, and production rules
5. Inference mechanism to employ a number of strategies;
    a. a least-commitment approach where decisions are reserved for the point in time when sufficient reliable information is accessible and when the inference is absolutely

essential.

b. Priority actions with contents prioritized and higher priority information used first in the reasoning process.

c. Forward chaining,and

d. Backward chaining mechanisms with

e. Methods and heuristics to prune the search space.

Newman(1987) suggests that a system operate as a "scheduling advisor", with an explanation facility.
in order to identify appropriate reasoning processes behind recommendations, Such an advisor would identify solutions through possible problem predictions and generation of possible solutions where appropriate. Using a look-ahead function, the advisor could project requirements for certain scarce resources and identify other problems.

4.4.6. Measurement of Successful Expert Systems

The success of an expert system can be measured in the following terms:

1. Creating structure in an unstructured or semi-structured environment(Boritz 1990),
2. Training novices and experts to better understand their domain,(Barr & Feiganbaum 1981),
3. Productivity gains of ten to a thousand times in the efficiency and effectiveness of the performance of a user.(Feigenbaum and McCorduck 1988).

4. User perceptions as described for DSS and Information Technology success measures earlier in this chapter.

Success measures for scheduling systems have not been specifically identified. The existence of operational scheduling systems which have reported measures of success could not be found(Steffan 1986). The nature of the successes described are expected rather than actual. Such success measures refer to improvements in the normal scheduling performance measures, such as:

1. mean tardiness,
2. Number of tardy jobs,
3. Machine utilization and the like.(Chryssolouris, Wright, Peirce, Cobb 1987).

4.5. CONCLUSIONS and the CASE DESCRIPTION OUTLINE

4.5.1 Chapter Purposes

In this chapter I have presented a discussion on the accepted wisdom related to DSS and ES technologies. The analysis has been structured to facilitate the testing of the main study hypotheses regarding the relationship between DSS and ES technologies and successful systems as applied to the GMI Scheduling problem. I expected two results from this analysis. The first was the identification of evidence that would suggest the validity of the hypotheses. The second was the formulation of the CDO.

4.5.2 Case Description Outline

Considering the CDO purpose first, I believe this goal was achieved. The Paradigm-Methodology-Model-Success structure that I defined for the analysis of the DSS and ES literature proved to be a usable and useful in the preparation of the CDO.
This Case Description Outline(CDO) is detailed in Appendix A1.

My intent in defining the CDO was to create a structure for a decision making process that would answer the questions:

1. Using the CDO; is the case an example of a DSS, ES or DSS/ES system ?
2. If it is, then, did the case result in a successful GMI scheduling system ?
3. If it did, then, which specific technology characteristics contributed to the success, and how ?
4. From #1, if the case was not an example of a DSS, ES or DSS/ES, then, why was it not, and did these differences contribute to success or failure?
5. From #2, if the case did not result in a successful system, then why did it not, and do these reasons support the accepted wisdom of the relevant technologies ?

The preparation of the CDO was an iterative process, not unlike the prototyping methodologies described in the chapter. In designing this tool I recognize that a structure has evolved, and that I have been the designer whose focus has been to support myself, the decision maker, in answering the above questions. The decision process or question answering is presented in Chapter 8.

To the extent that I have demonstrated any competence at this task I have been the knowledge engineer, conducting knowledge acquisition from a collection of unseen experts(authors), who have reported upon these fields. The result, the CDO(Version 1.0), could be represented in an expert system knowledge base which could be used to prompt a user to complete the CDO and then to assess the veracity of the relevant hypotheses. The assessment process presented in Chapter 8, in theory could also be replicated in the associated expert system.

I have no doubt that the CDO is neither complete nor optimum for the purpose intended. However, I am comforted by the thought that, as with the many successful DSS and ES systems, its evolution will continue, either by my hand or by another. In Appendix A2, is a representation of a smaller comparison derived from comparisons tables developed by Harmon & King(1985) and Chryssolouris et al (1986). Although the appendix illustrates the comparison of the three cases according to their criteria, I believe the CDO derived in this study is more suitable for this research.

4.5.3 Validity of the Hypotheses

The second purpose of this review was to obtain evidence from the literature to test the validity of the hypotheses. I have found both supporting and refuting evidence, as presented below.

The evidence from the literature review, concerning the application of DSS to GMI scheduling includes the following:

A. Supporting

1. Alter(1980) described DSS representation, suggestion and optimization models, that could include scheduling models.
2. GMI Schedulers do exist and thus could be the focus for the prototyping of a DSS.
3. The basic development of a scheduling DSS, however simple, seems a reasonable expectation, given the wide success of DSS's in many applications over several years.

B. Contradictory

1. No scheduling DSS's were identified in the literature reviewed.
2. Although a simple scheduling DSS seems achievable, its useability and usefulness over time cannot be assumed, based on the literature review.

The evidence from the literature review, concerning the application of ES to GMI scheduling includes the following:

A. Supporting

1. Fox (1986), Newman(1987) and Nassr(1985) described the application of ES techniques to scheduling problems.
2. GMI Schedulers do exist and thus could be the focus for the prototyping of an ESS. Conceivably, a scheduler could become quite proficient using a DSS that his relative performance could be perceived and accepted as expertise, and he the expert. As an expert, the necessary requirement for an ES would exist. The result

would be an ESS.

3. The basic development of a scheduling ESS, however simple, seems a reasonable expectation, given the existence of Ess in many application areas.

B. Contradictory

1. Only two scheduling Ess were identified in the literature reviewed, and neither is a significant success.

2. Although a simple scheduling ES may be achievable, its useability and usefulness over time cannot be assumed, based on the literature review.

3. Fox's(1986) doubt in the existence of an expert scheduler implies that the development of an expert scheduling system may not be possible.

The evidence from the literature review, concerning the combined application of DSS and ES to GMI scheduling includes the following:

A. Supporting

1. Each of the arguments supporting DSS and ES separately may be used as supporting evidence.

2. The specific DSS contradiction of no scheduling DSSs is weakened by the existence of a few scheduling Ess.

3. The question of the existence of an expert scheduler is no longer necessary from a DSS/ES viewpoint. GMI Schedulers do exist and thus could be the focus for the prototyping of a DSS/ES.

3. The basic evolutionary development of a scheduling DSS enhanced with selected ES elements, however simple,

seems a reasonable expectation, given the success of DSSs and Ess in many applications over several years.

4. A small core of researchers have reported some success in the integration of DSS and ES technologies.(Turban and Watkins 1986, Bonczek et al 1981, Dutta and Basu 1984, Kusiak 1986, Newman 1987)

B. Contradictory

1. No such DSS/ES scheduling systems have been reported in the literature.
2. Although a simple scheduling DSS seems achievable, its useability and usefulness over time cannot be assumed, based on the literature review.
3. The complexity of the scheduling problem(i.e. combinatorial optimization) and the apparent need for tight integration with the production systems, present a formidable challenge.

The foregoing discussion on the potential for success in the application of DSS, ES and DSS/ES to the scheduling problem in the GMI is not conclusive. The fact that it is not conclusive is further justification for this research.

CHAPTER 5 - CASE I: SCHEDULING SYSTEM PROJECT I

5.1. RELEVANCE TO THE STUDY

This case is very important to this study for the following reasons:

1. From a GMI perspective, the case traces the events and activities that transformed the scheduling function from dismal failure to an essential component in the company's operations. The key decisions, both good and bad, that accelerated and retarded the transformation, are identified.
2. From a DSS perspective, this case is an example of the successful application of DSS technology applied to the GMI scheduling problem. Many aspects of accepted DSS wisdom are evident in this case.
3. From an ES viewpoint, challenges are identified in the form of the limitations of the DSS solution, and the nature of the GMI scheduling environment.
4. From a research viewpoint, I played the roles of an active participant, a change agent, and subsequently, a reflective researcher; searching for the true cause and effect relationships that determined the significant outcomes. The concise documentation of the case from the DSS and ES viewpoints has been a challenge and I have had to omit many anecdotes that would have made interesting reading.
5. From a personal view, this case was the source of my research interest in GMI scheduling, and the consideration of DSS and ES solutions. This interest has occupied a major portion of my life since 1984, and has led me to study these fields in the United Kingdom, Europe, the USA and Canada.

The calendar below indicates the approximate timing of this and the other two cases.

	1983	1984	1985	1986	1987	1988	1989	1990
Case I	**	****	****	****	**			
Case II						**	**	
Case III					**	****	****	****

5.2. ROLE OF THE RESEARCHER

My involvement with this company began in 1981, when I was retained as an external consultant to advise and assist senior management in the implementation of Information systems and equipment throughout the company's operations. The time I spent with the company varied between 15 and 39 hours per week. Reporting to the Chairman of the company, and working with the senior executive, my assistance to the company was significant and in the period from 1981 to 1987, and resulted in the successful installation of MRP, Production Control, CAD and accounting packages, the design and development of pioneering systems for Product Development, computer assisted product specifications, retail management, and production scheduling. During this period, I led the planning and installation of IBM/38 computers in Winnipeg and Los Angeles, and IBM PC's throughout the company's operations in six centres in North America and Hong Kong.

By the time I became involved as a member of the team to solve the scheduling problem, I had established my credibility with the company as a result of guiding the successful implementation of comprehensive MRP and production control systems.

During the period described in this case(1983-1987), my roles were:

1. Project leader, chief designer and developer of the Scheduling DSS, supervising the work of the analyst assigned to this project.
2. Team member, with the Director of Manufacturing and the Scheduler.
3. Chairman of the Scheduling Committee(Nov 1984 - May 1986).
4. Advisor to the Scheduling Committee(May 1986 - May 1987)
5. Researcher for this study (Jan 1984 - present)
6. Corporate systems consultant(Sept 1981-June 1987)
7. Confidential "mentor", and often, mediator.

5.3. RULES OF EVIDENCE

As a researcher I was continually aware of the need to document and to retain detailed records of the events and related documentation. As a result of this awareness, I accumulated 10 volumes of daily journals, multiple file folders containing scheduling related materials, computer listings and reports, meeting reports, memoranda, and scheduling related reports, articles, and external information. Periodic memoranda and reports describing conclusions, recommendations, or decision points were retained. A clear record of my time and activity, was necessary since weekly time sheets were submitted with each invoice. Since one of the results of the project was a Lotus 1-2-3 system, many printouts of the many system versions were filed. These files and records, from which this case has been recreated, provided a clear depiction of the chronology and content of the events and results of the project. These records are described in Figure 5.1, Case I Documentation.

The recording of the major events and activities of this case was not difficult since I was living these as they were being recorded. I have been guided in this task by the works of Sims (1978), Armstrong (1979), Cumberlidge (1982), Brewer (1981), Bennett (1986), and Hillway (1964). The most difficult aspect of describing the four year period researched in this case has been to limit the amount of description which could be endless. I have used summarized tables to attempt to succinctly describe the relevant main events of this case. Thus it is with guarded confidence that I have documented this case and I believe it to be an accurate and factual reproduction of the major relevant events and results of this project. The interpretation of the results, I attribute only to myself. As with the other two cases, reflection of the facts of the project has been a rewarding and illuminating experience.

In the words of Brewer (1981), I became a "change agent". As he found in his research, being both an internal change agent and a researcher, involves the necessity of retrospective reflection, the accumulation of copious notes, and consideration of their use at specific points in time in order to ensure that the trends and events can be seen in context of a research study.

As Brewer(1981) found:

> "An internal change agent is part of a dynamic organizational political matrix which influences the design and development of change prospects." (pp. 503)

There is no question in my mind that the changes which came about in this garment company did so in large measure because of my role as a change agent. Brewer(1981) found his role the same. Whether this role makes this research more or less valuable is a case for discussion. Like Brewer(1981), I believe this role is a valid one for such research as it offers a perspective of an active participant, one who feels the emotion, frustrations and enthusiasm as events unfold, problems occur, and progress is achieved. As Preston (1981) found in his research, even an impartial observer who is positioned as such within an organization eventually becomes a participant through the natural political process of the players involved in that situation.

The Case Description Outline(CDO) for the case is appended as Appendix B1. The CDO was a useful guide to identify the important observations of the case. At the same time the importance of the "degree" of certain factors could not be adequately expressed by the CDO. These have been described separately.

Figure 5.1.

Case I Documentation

Period	Document	Content
08/83	Conceptual Model	Original Scheduling Model as an LP problem.
08/83-05/87	Weekly Time sheets	Date, hours spent, names location, brief agenda
08/83-05/87	Daily journal	Date, names, agenda, notes(minutes, results,concepts, musings, etc)
08/83-05/87	Report samples	Copies of informal scheduling related meeting reports
11/84-05/86	Meeting reports	Weekly Scheduling Committee agenda,regular weekly reports and supporting documents, meeting minutes, personal notes.
08/83-05/87	1-2-3 Reports reports & notes.	Copies of new system
06/84	Trip Report	Report of Trip to UK and Finnish companies
09/84	Bobbin Show Report	Report of Scheduling systems available at the 1984 Bobbin show
05/85	Scheduling Review	Observations, Conclusions and Recommendations of the review.
06/85	IMB Show Report	Report of Scheduling Systems available at the Cologne IMB Show

5.4 THE SETTING

This case began with the meeting described in the Introduction of Chapter 1., between the Chairman of the Company, the Director of Manufacturing and myself. Beginning with that meeting, I worked with the scheduling, manufacturing, operational and systems personnel within the company in an attempt to develop scheduling systems, procedures and practices that would result in a more effective scheduling function and which would minimize the late customer delivery problems. The Production organization of the company is illustrated in Figure 5.2.

At the time of the above meeting, the company was in the midst of shipping customer orders for the Fall'83 season, The scheduling function was being performed by two staff who were using a text editor in the IBM/38 to attempt maintain the schedule. I have referred to these staff as Group 1 in figure 5.2. The analysis of the delivery statistics by the senior management concluded that several deliveries to customers would be late, with the result that the company had to discount the merchandise or cancel the shipments, The Group 1 schedulers were assigned the responsibility to avoid late deliveries and thus were accountable. Their performance as schedulers was deemed unacceptable and they were replaced shortly after I became involved. Subsequently, my involvement continued, in detail, with new players identified as "Group No. 2".

5.5 DESIGNING THE SYSTEM

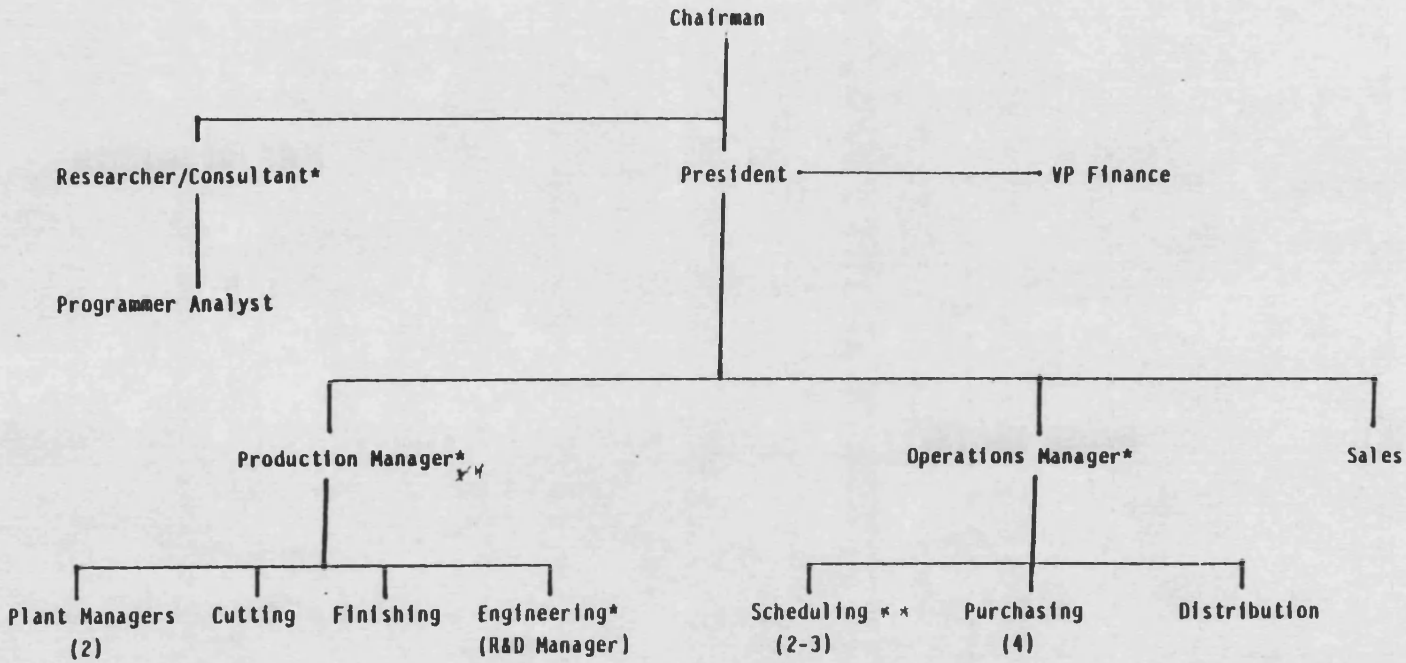
5.5.1 Evolution of the Scheduling System

The main events surrounding the evolution of the scheduling system are highlighted in Figure 5.3. In this table, the time period, the participants, the type of system used, and the performance or other conclusions related to these events are identified. The period of time covered is from June 1983 to June 1987.

The progression of the scheduling systems from manual, clerical to DSS was marked by specific identifiable events. Initially in period A, Group 1 staff were attempting to gain control of the mass of information that was available. Their fundamental methods were based on the concept that load and capacity could be measured in "units" of production within the general classification of tops and bottoms. Tops included jackets, blazers and variations of the same. Bottoms included pants, trousers, skirts and shorts.

The several manufacturing facilities available for production were also categorized as tops or bottoms oriented. Each facility was rated as capable of producing a given weekly "unit" output of that type of garment.

PRODUCTION ORGANIZATION CHART



** Group 2 Scheduling Department and Plant Manager.

* Scheduling Committee formed in November 1984.

FIGURE 5.2
PRODUCTION ORGANIZATION CHART

Time Period	Scheduling Department	System	Performance/Conclusions
I. Nov 84	Group 2	Same.	Committee begun to meet weekly to improve scheduling performance; composed of Production, Purchasing Operations, including Distribution, Engineering, Schedulers and Researcher.
J. Nov 84	Group 2 plus Committee	Same - with Committee to examine in detail all aspects of systems, etc.	Conclusion: 1) Inadequate communication between Scheduling and Purchasing and false assumptions used by Scheduling. 2) Original load vs capacity plan is good on paper but is not implemented because: a) it is unrealistic; or b) not followed for execution.
K. Dec 84	Same	Purchasing and Scheduling prepare fabric delivery plan - plan shows several serious delivery problems by fabric. Corrective actions begin to be identified and pursued.	Conclusion: 1) Heavy Production Load is building up - inevitable late deliveries - realization of need to contract work out to contractors. 2) More Cutting Room capacity needed - reluctance on part of Production to respond based on prior "false alarms" in past years.
L. Jan 85	Same	Both Load vs Capacity Plan and Delivery Plan show crisis situation - "is it believable?". Begin use of a weekly Summary Report to review key indicators - manually prepared from Micro plans.	Major meeting held to deal with crisis - several thousand units contracted, - recommendation for long term capacity planning by type of production to allow plants to be reconfigured to future work.
M. Feb - Mar 85	Same	Increased involvement of Committee in both plans.	Performance of fabric deliveries greatly improved, late fabric problems cease. Continued poor performance of cutting room versus targets.

Time Period	Scheduling Department	System	Performance/Conclusions
N. Apr - May 85	Same	Plans indicate a high build-up and backlog of work in May and June - believable but cutting room problems still not accepted.	Decision to contract work taken. Possibility of Union Strike appears - Scheduling strategy changed to minimize effect of strike. Internal review of all possible system improvements.
O. May 85	Same	Recommendation to begin short term planning and control system to ensure that the loading plan is implemented. Plans are reviewed less and less by Committee as they are seen to be correct - cutting capacity continues to be a problem. Recommendation to set up a Cutting Buffer and to calculate Cutting load vs capacity and include same in production load vs capacity plan. Senior management reviews all computer systems. Places importance on Scheduling systems for improvement.	
P. July 85	Same		Senior management decision to re-allocate systems staff to develop Retail Computer System - efforts to work on Scheduling systems postponed.
Q. Aug 85	Same	Same	Customer deliveries are still a problem. Co. hires methods analyst (scheduling and distribution experience) to look at Scheduling. Conclusions: Key staff must attend all meetings and "Shop Floor Control", i.e. Cut Control is weak. Cut Control Worksheet is developed for trial-run (see Figure F).
R. Oct 85	Same with Methods Analyst	Trial "Cut Control Worksheet" is used on one production line.	

Time Period	Scheduling Department	System	Performance/Conclusions
S. Nov 85	Same		Realization by Co. Management that sales growth is higher than expected - up 40% - direction given to hire more operators and to contract more work.
T. Nov - Dec 85	Same with VP-Finance		Co. VP-Finance asked to attend Scheduling meetings regularly - very positive in ensuring senior directives are implemented.
U. Jan 86	Same with VP-Finance	Weekly Meetings. Agenda is refined; Contractor and other reports are included.	
V. Jan 86	Same.		Proposal to Management for full implementation of Cut Control System and additional micros mode. Proposal developed by researcher from Sept 85 to Jan 86. Proposal approved - to commence work in April 86.
W. Feb 86	Same with fewer staff at Weekly Meetings.		Weekly Meeting changes - fewer attendees only VP-Finance, Director Manufacturing, Director Operations, Scheduler and Researcher. Results - meetings shorter and appear more efficient, senior management direction very clear.
X. Feb 86	Same	Fabric Delivery Worksheet and Cut Control Trial are ceased due to lost staff.	An engineer working on Fabric Delivery and Cut Control systems is transferred to one of the plants - Replacement does not last - job is unfilled.
Y. Mar 86			Sales drop is realized - it appears company sales will not grow this year. Production told to cut back.

Time Period	Scheduling Department	System	Performance/Conclusions
Z. Apr 86			Analyst assigned to begin work on Cut Control system as proposed in Jan 86. Additional PC-AT purchased for Scheduling. At end of April Analyst was reassigned to another Project.
AA. May 86	Same	Same. Second PC-AT allows Scheduling Assistant to have a dedicated micro - suggests improvements.	Director of Manufacturing suggests minor changes to the regular Weekly Computer Reports - these are made.
		Researcher investigates and determines that two Directors are "hiding" mistakes from Committee due to presence of VP-Finance. Scheduler being told not to highlight problems.	A late fabric problem is identified in Weekly Meeting - this is seen as a direct result of not operating the Fabric Delivery system. New situations come to light at Weekly Meetings that Director of Manufacturing has been discouraging sub-contracting to keep plants busy.
AB. May 86			VP-Finance freezes all hiring plans due to small sales decrease becoming apparent. All departments told to reduce 1-2 staff or increase productivity.
AC. July 86 - January 87	Same	Same system with minor automatic summarization features added.	All involved realize that although most of the input information is on the main computer. All the Systems staff are reassigned to other projects
AD. Feb 87	Same	Same	President calls a meeting to investigate how a special cut was "lost" for several weeks. Answer - the Cut Control System (see Tune Period X) would have prevented this but no staff had been assigned to continue its use.

Time Period	Scheduling Department	System	Performance/Conclusions
AE. April 87	Former Scheduler (since 1983) is promoted to Plant Manager for a main plant as part of several reorganization moves. Former Assistant Sales Manager - Customer Service Manager becomes new Scheduler. Assistant Scheduler remains and continues to run the systems.	Same	All former Scheduler's experience is lost! Scheduler suggests easier form of inputting data - same as conclusion of 2 years ago.
AF. June 87	Same	Same	New Scheduler continues learning the role, begins to read more Production/Operations Management articles in the hope to find an easy solution. Director of Manufacturing comments "He has a long way to go and he's only starting."

To assist in recording and changing their weekly schedules Group 1 used a text editor on the company's main computer. The Scheduling department had its own video display terminal and obtained printed output on a printer in the same building. The text file was updated to record monthly plans for two months (8-9 weeks) into the future. With the continual introduction of new lines the two man department could barely keep up with the work.

When an important delivery period for one season was reviewed by senior management it was clear that the long term problem of late deliveries was not being solved by this team. In a dramatic move the Director of Manufacturing, and the Scheduling Supervisor were re-assigned, an intermediate step to their eventual departure from the company along with an engineer who had been part of this team. The heir to the senior manufacturing job was a successful plant manager who prior to his appointment had enlisted my assistance to review the possibilities for computerization of the scheduling function. From "inadequate" knowledge I formulated the problem as a linear programming model then realized that to jump from a manual system to this model without any staff or support systems would be impossible. An alternative Lotus work sheet was designed to represent the load vs capacity by facility and week, using "standard minutes" instead of units.

This work sheet was shown to the soon-to-become Director of Manufacturing prior to the meeting called by the Chairman of the company. Shortly after the soon-to-be Director and I were called into the meeting with the Chairman. The title of Director of Manufacturing was confirmed by the Chairman.

The new Director was asked for his general approach which he described as being in two parts. Part one to divide the facilities into sewing lines that would specialize in the type of garment being manufactured in each such line(eg. pants). Part two was to initiate a scheduling activity based on the concepts of the preliminary Lotus work sheet I had prepared. The chairman briefly reviewed the work sheet and agreed to this project.

Shortly after a new scheduler was hired with the approval of the Director of Manufacturing. However, for unknown reasons, this scheduler now reported to the Director of Operations. Thus, the stage was set for the development and enhancement of a decision support system that gained acceptance and approval by senior management.

5.6 THE DESIGN PROCESS AND DESIGN REPRESENTATIONS

This development began in period B when I called a meeting of what was to become the new Scheduling department and the future Scheduling Committee (although this committee was not created for several months). At this meeting, with the foregoing organizational events clear in everyone's mind, there were no objections to the commencement of the new effort to use an IBM-PC, the Lotus package and the concepts of the initial work sheet. This direction was pursued with considerable maintenance/enhancement work for several months through periods C to J. This basic system became the basis for all future system enhancements and additions.

It is relevant to note that the new Scheduler and I worked very closely together initially and our close association continued throughout the project. We developed the work sheet concept into a Long Term Load Plan for the period from 16 to 48 weeks into the future and into a Mid Term Load Plan (Figure 5.4- Load vs Capacity Plan) for the period 1 to 16 weeks into the future. Gaining the efforts of a senior programmer analyst was another result of the events surrounding the "new direction" of Scheduling. This analyst carried out subsequent maintenance/enhancement and new development under my direction.

From discussions with the new Scheduler and new Production Manager from Group 2 the decision was made to use "standard allowed minutes"(SAMS) as the measure of the amount of labour effort required to sew and finish one garment. SAMS would also be used to measure the available capacity in each manufacturing facility. This led to the development of a few conceptional Lotus work sheets which eventually led to the development of the "load vs capacity plan"(Figure 5.4) initiated in period B.

Subsequently this work sheet was used for all styles and all manufacturing facilities being controlled by this Scheduling department.

The intent of the original Lotus model was to develop and test a prototype which if useful would subsequently be developed into an integrated system on the company's main computer.

After the rapid acceptance of the initial model and its implementation it was determined that the system would require too much CPU resource on the main computer and should remain on the micro (IBM-PC) with future transferring of required data from the main computer to the PC. In the four year period studied the requirement for this integration was highlighted several times but never completed.

At the end of period C, buoyed by the momentum of the Loading Plans, a Cut Scheduling (Figure 5.5) system was requested by the Scheduler. This system was designed according to the Scheduler's specifications to manage the issued cutting orders in the immediate three weeks prior to going into sewing. This schedule filled a gap of identifying to the Cutting Supervisor which cuts were needed by when. Eventually a weakness in this schedule was discovered. There was no direct control between the Mid Term Loading Plan and this Cutting Schedule to ensure the execution of the Loading Plan.

The next major event, although less dramatic came about in period E, when the Chairman was influenced to make a decision that too many systems staff resources were being spent on production related systems and it was time to address the Product Development area. This decision had the effect of stopping any new activity in the Scheduling area. A major new information system resulted to support Product Development.

In period D I was called to join a meeting in progress between the production manager and the scheduler, both of whom were avid sports fishermen and hunters. This common bond was maintained throughout the research period in spite of several challenges to their close association. It was at this meeting that another pending crisis of late deliveries to customers and low work-in-process in the plants was identified.

During the ensuing discussion it was agreed that this problem could only be caused by late fabric deliveries. A decision was made to develop a Lotus work sheet as a Fabric Delivery Plan(Figure 5.6) to ensure that Purchasing and senior management could see the required lead time to order the fabric in order to ensure adequate time to produce these goods.

Although this decision was correct and proved beneficial, in retrospect its basis was not entirely correct. This crisis of late deliveries and low work-in-process in sewing could also have been caused by a bottleneck in the cutting room, a situation which did not become apparent until the late fabric delivery situation was resolved. Once the Fabric Delivery Report was developed I began to realize that a fundamental weakness in the systems being employed was that there was no easy transition from the "load vs capacity plan" to the "Cutting Schedule". Cuts could be issued without regard for the planned loading of a given style into a particular facility. This problem became one of the fundamental questions to be researched in the visits to garment companies in England and Finland and in the September trip to the Bobbin Show in Atlanta, Georgia, USA, in time periods F & H. (Peterson 1984, 1985)

Although systems resources were scarce for the Scheduling department, contact remained and problems were monitored. Through this contact and the meeting with the Director of Manufacturing and the Scheduler in period D, the problem of the control over the execution of the loading plan became more evident.

The new "Fabric Delivery Plan" (Figure 5.6) was to be implemented by the Scheduler. He could not allocate sufficient time to it until period G when a few minor enhancements were made to it.

During this period I visited garment companies in Finland and England. One conclusion of the visit to the English and Finnish companies was the need to have weekly Scheduling Meetings to coordinate all aspects of this process. In period H, I issued a memo requesting the staff, who became the Scheduling Committee, to attend a meeting to discuss this and other problems of performance. Coincidently, the Chairman of the company asked the Computer Department to look into the serious problem of late deliveries two days after this memo had been issued.

With the chairman's interest the meeting was well attended and it was agreed at its conclusion that these meetings should be held weekly until all the problems were identified and systems and solutions in place.

I now assumed a role of informal chairman of this committee although having no formal authorization other then a clearly stated objective of wanting to see that the problems were solved.

In this role I now became a participant and a motivator towards identifying problems and solutions. Having no organizational ties to Production nor Operations also created a mediation role when needed. These weekly Scheduling Committee meetings continued from period I to Y.

The activities of this committee focused on correcting late fabric deliveries. This correction occurred largely due to the close working use of this Plan by both the Scheduler and the Purchasing Manager, who was now scheduling his major purchasing decisions according to this plan.

This "Fabric Delivery Plan" gained in importance to the Committee as both it and the Loading Plans became better understood. A Product Manager trainee, working for the Purchasing Manager was assigned to maintain the Fabric Delivery Plan.

Out of these deliberations a procedure was proposed of how a new "line" should be scheduled.

This procedure consisted of the following steps:

1. Set up the new line's fabrics on the Delivery Plan to reflect:

   a. The time required to receive the fabric (mill production + delivery time = lead time) and to produce the garments in time for customer delivery.

b. Load the Loading Plan with the new styles into the appropriate sewing lines according to the time when the Delivery Plan indicated sewing was to start.

c. Evaluate the Loading Plan determining from the work-in-process which styles could not be completed on time, then in consultation with the Purchasing Manager select fabrics and their styles that could be received from the mills sooner and thus put into production earlier.

d. Revise the two plans and repeat steps b & c as required.

e. When a realistic plan was agreed to, the Purchaser would make appropriate decisions as scheduled.

The result reduced the number of late fabric problems, until period "X" when a staff turnover left this system without an operator. As a result of implementing this procedure the corporate goal of minimizing raw materials inventory was assumed to be achieved. In addressing this goal and implementing the above procedure the operations of Scheduling were seen to have improved and less Committee time was spent on both the Fabric Delivery Plan and the Loading Plan. This allowed the committee to focus on other indications of problems.

The next area to be tackled was that of the total number of units per week to be cut by the Cutting Room. These numbers were totalled from the Load Plan for each sewing line. These weekly totals showed peaks and valleys throughout the year. Previously it was assumed that the

Cutting Department could raise and lower capacity to ensure the sewing lines were kept busy. In reality upon close analysis, this assumption was false. This led to the realization that the Load Plan for each sewing line may not be achievable if the Cutting Room capacity was exceeded.

The analysis of the factors effecting the cutting load was then undertaken. As an interim measure it was proposed that the Cutting Supervisor be given a clear weekly plan of total units to be cut, the number of cuts required and the nature of the fabric. (Some patterned fabric requires matching of each layer of cloth significantly increasing the total cutting time.) This met with limited success since units are a poor approximation of the actual work content in minutes for both load and capacity.

The next major event was a report by the Director of Manufacturing to the Senior Management Committee in period N. This report was a surprise to the remainder of the Scheduling Committee because it was not forewarned. In addition many of his criticisms of the systems had been identified in committee meetings and were not being pursued because of other committee activity. This report resulted in a review by another analyst.

This illustration shows the effect of this intervention on the development and enhancement of these systems. The intervention by the Director of Manufacturing had the effect of the initiation of another review which resulted in the acceptance of the concept of a short term planning and control system to ensure the issuing of cuts, the marking, cutting and sewing activities reflected the Mid Term Loading Plans. This system was not implemented due to reassignment of the systems staff (Computer Dept) in period "P". Interest was renewed in this concept when a new Methods Analyst was hired in period "Q" and this became the subject of one of his recommendations. The resulting trial system was called the Cut Control System. Its main output is illustrated in Figure 5.7.

Through the Cut Control System several improvements were expected, including:

1. As a means to implement "style loadings by week" from the "Load vs Capacity Plan" (Fig. 5.4) into production at a specific sewing line at the planned date.
2. To provide Cutting, Marking and the Plant managers with a weekly plan of their required load, which if excessive, required them to obtain approval for changing these detailed cut schedules. Such approvals could be given only by the Director of Manufacturing and the Director of Operations and then reflected by Scheduling on these Cut Control Plans.
3. As a feedback mechanism to monitor actual progress against plans. This feedback would pinpoint reoccurring bottlenecks and other problems.
4. As a means of analyzing specific styles to determine if delivery problems were going to occur and to make appropriate changes when possible.

LOAD VS CAPACITY PLAN

Facility: Central #1 Date: Wk 1

LOAD PLAN

LINE	STYLE	EST'D SALES	STD MINS	WK 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Spring	X3201	3000	12.3								1000	1000	1000						
	X3205	2000	15.6									1000	1000						
Summer Moods	X0910	12000	19.7														4000	4000	4000
	X2301	4500	18.3												1500	1500	1500		
TOTAL STD MINS																			
TOTAL UNITS				39375	31500	31500	31752	31752	42630	51156	44100	56700	60750	60750	40500	60750	50625	40500	40500

CAPACITY PLAN

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
No. of Operators	25	25	25	27	27	29	29	30	30	30	30	30	30	30	30	30
Efficiency %	75	75	75	70	70	70	70	70	75	75	75	75	75	75	75	75
Min/Day/Operator	420	420	420	420	420	420	420	420	420	450	450	450	450	450	450	450
Avail. Std. Mins.	7875	7875	7875	7938	7938	8526	8526	8820	9450	10125	10125	10125	10125	10125	10125	10125

SUMMARY ANALYSIS:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Days Work Loaded	5	4	4	4	4	5	6	5	6	6	6	4	6	5	4	4
WIP	20	19	18	17	16	16	17	17	18	19	20	19	20	20	19	18

One such plan is maintained for each facility. It is updated weekly or more often if problems are seen and "what if" situations are needed to evaluate alternatives.

Figure 5.4
Load vs Capacity Plan

CUTTING SCHEDULE

CUT NO.	STYLE	DATE ISSUED	DATE MARKED	DATE REQUIRED (OUT OF CUTTING)	
635	X0201	84/12/2	84/12/6	84/12/18	) Late Cuts
693	X3231	85/01/03	85/01/05	85/01/12	
752	X4321	85/01/03		85/01/21	

This schedule is updated automatically for cuts issued and completed. The "Date Marked" is input. The Scheduler inputs the "Date Required" which is then used as the sort for the sequencing of the report.

When a cut is completed, it automatically is removed from the report.

This system is integrated with other systems which have as their inputs the date a cut is issued and when it is completed.

FIGURE 5.5
CUTTING SCHEDULE

FABRIC DELIVERY PLAN

DATE OF REPORT: WK 2

LINE ID	FABRIC ID	MILL	LEAD COLOR	TIMES TRANSIT	QNTY	UNIT OF MEAS.	STATUS /DEL #	WK # 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
																					(Line Delivery)		DEL	
"Summer Moods"	X09-Cotton - Stripe	Italy 2	4	4	10000	Yds	Del 1		Color				Ship				Rec	Iss	Mrk	Cut	Sew	Sew	Sew	Fin
					5000	Yds	Del 2				Color				Ship				Rel	Iss	Mrk	Cut	Sew	Sew
	X23 Denim	Con #1	2	2	5000	Yds	Del 1		Color			Ship			Rec	Iss	Mrk	Cut	Sew	Sew	Sew	Sew	Fin	Dist
	Revised Wk 1 - Colors in Stock WIP Lowered						Del 1				Color		Ship			Rec	IssMrk		Cut	Sew	Sew	Sew	Fin	Dist
	X43 Linen	Orient 2	N/A	6	10000	Yds	Del 1		Ship						Rec	Iss	Mrk	Cut	Sew	Sew	Sew	Sew	Fin	Dist
	Revised Wk 2 - Shipping Late - Push Rec, Issue, Mrk. Cutting to Gain 1 Wk.						Del 1			Ship						Rec	I,Mrk,Cut		Sew	Sew	Sew	Sew	Fin	Dist
	X51 Silk	Orient 1	N/A	6	15000	Yds	Del 1				Ship						Rec	Iss	Mrk	Cut	Sew	Sew	Sew	Sew
	Revised Wk 1 - WIP Too High to Meet Deliveries, Contract to Silkworks Co. Arrange Contracts Immediately						Del 1				Ship						Rec	Iss	Mrk	Cut	Sew	Sew	Fin	Dist

This worksheet is reviewed bi-weekly for long term fabric delivery problems and appropriate reaction. It is updated weekly.

FIGURE 5.6
FABRIC DELIVERY PLAN

CUT CONTROL SYSTEM

STYLE/ MODEL	CUT NO.	UNITS	STATUS	WK. # 10	11	12	13	14	15	16	17	18	19	20
X23	X23-01	500	Plan		Issue	Mark	Cut	Sew	Sew	Sew	Fin	Dist		
X23	X23-01	495	Act		Issue	M/Cut			Sew	Sew	Sew	Fin	Dist	
. . .														
X99	X99-02	300	Plan							Issue		Mark	Cut	Sew
X99	X99-02	300	Rev 1								Issue		Cut	Mark
X99	X99-02	300	Rev 2								Issue	Mark	Cut	Sew

FIGURE 5.7
CUT CONTROL SYSTEM

In Period S, the management saw the potential to exceed its sales plans for the Spring'86 season, and brought the challenge to the Scheduling Committee. The revised sale estimates were input into the schedule and the amount of labour needed was identified. The Dir. of Manufacturing agreed that more operators had to be hired and the balance of work would have to be contracted. This situation focused attention to an ongoing issue of whether to contract work. The Dir. of Manufacturing always took the side on producing in house rather then contracting. Lengthy arguments were often held in attempting to resolve this issue. It was not until some time later that I became aware of the nature of his insistence. The Dir of Manufacturing's bonus was based on the average unit cost of production. He was motivated to maximize the number of units produced which reduce the unit cost by spreading the fixed overheads and by increasing the utilization of the work force. When I brought this to the attention of the VP-Finance, we agreed that he should attend the next Scheduling Committee meeting to ensure that the Dir. of Manufacturing be directed to pursue ta course that would achieve customer delivery dates.

In Period T, the VP-Finance attended the meeting and ensured that the decisions reflected the focus on customer delivery dates. His involvement continued for the remainder of the period studied. With his authority apparent, the meetings changed from open discussions to careful analysis of the current and expected situations, and the appropriate decisions. The need for the Cut Control Systems was evident and the VP-Finance approved the purchase of a new PC and the assignment of another staff member to the job of maintaining this system.

The focus on the information required by the VP-Finance led to minor refinements to the systems and to the preparation of summaries for the Scheduling Committee meetings. Another request was that these status reports be sent to the committee members the previous day so the meeting time could be reduced to the answering of questions and consideration of the man issues, rather then a complete discussion of every report. In the remaining periods fewer staff were seen to be needed in the meetings due to the changed format.

In Period Z, the analyst who had been working on the Cut control system was reassigned to fill a position left vacant by a resignation at one of the plants. The Cut Control system was to be operated by the Scheduling Assistance but he did not have the time, so it was not maintained.

In Period AA, I was asked to meet with the Scheduler, on a confidential basis. He indicated to me that he was being pressured by both the Dir of Manufacturing and the Dir of Operations, at different times to change the information of the pre-meeting reports to minimize the problems that were their respective responsibilities. While this had the potential of becoming a major problem, it was foreshadowed by the drop in sales for the next season. The VP-Finance initiated a staff cut in all departments, and a goal of increasing productivity. The re-entry of data by the schedulers was identified as a source of a potential staff reduction in Scheduling. The system resources were all assigned to higher priority projects and thus no further integration functions were added.

In Period AD, a cut for a critical order was lost, and the President called a meeting. The resulting heated discussion concluded that the cut would not have been lost if the Cut Control Systems had been in operation.

In period AE, as the financial picture worsened, the company undertook a major reorganization, which promoted the scheduler to a plant manager, re-assigned the VP-Finance to another major area of the company and reduced my involvement. The Scheduling Committee now became the meeting of the new Scheduler, the Director of Operations and the Dir of Manufacturing. This re-organization marked the end of the case.

5.7. THE RESULTS

5.7.1. Positive Results:

In general, the results of the many events and activities that occurred in the period August 1983 to May 1987 were of benefit to the company and to certain individuals. These benefits, both tangible and intangible are summarized accordingly:

1. Throughout the case period the versions of the DSS were used by the Scheduler and his assistant to prepare, update and manage the plant schedules for the company.
2. In Period L-Jan'85, the system highlighted a major shortage of capacity that would result in late customer deliveries. After detailed review by several production staff, the system was seen to be correct and several thousand units were contracted to external plants.
3. From Period L to the end of the case, the system was used to plan for and manage external contractors. A benefit from this ability was that the company was able to arrange for subcontracting earlier than its competitors.
4. The Fabric Delivery Plan, and the related procedures contributed to a closer coordination between the fabric purchasing and production departments, with an improvement in customer deliveries resulting(Period M+).
5. In Period N, the system was used to analyze the impact of a heavy work load and a possible union strike. Several options were evaluated for senior management.
6. In Period S, the impact of the 40% sales increase was

analyzed. Contracting and expansion plans were prepared and executed by the Scheduling Dept. The company had a record season, as a result. In Period Y, a dramatic sales drop was also managed successfully.

7. New engineering and production staff were frequently brought into the Scheduling Committee Meetings to learn the interrelationships of the manufacturing facilities.
8. In the three major planning sessions held each year, the next year's production plans were modeled using the system and used by senior management to ensure manufacturing plans were consistent with corporate plans.
9. The success of the Scheduler(1984-1987) led to his promotion to Plant Manager in 1987.
10. Over the four year period, the key production , purchasing and scheduling personnel worked in relative harmony to effectively schedule and manage the production and fabric acquisition functions of the company.
11. From a research viewpoint, the four year period was a successful project for studying the scheduling problem in the GMI.
12. The use of the system highlighted several secondary problems in the entire production process.

    EG. Assumption that cutting had excess capacity,
    Cuts were managed correctly be the plants.
13. Hidden agenda, by various players were difficult to hide.(Period AA).

5.7.2. Negative Results

Although the overall results of the events and activities were of benefit to the company, a few problems resulted from the growth of the DSS. These included:

1. The successful operation of the systems and the Scheduling Committee were dependent on an external consultant until Period AB, May'86, when the VP Finance became Chairman.
2. In Period AE, April'87, the promotion of the Scheduler to a Plant Manager, left a void in knowledge and prominence to the Scheduling function.
3. The cycle of allocating systems resources to the Scheduling function then to other departments led to a discontentment among those who wished to see the consistent development of the Scheduling systems. The momentum for change and progress was lost. Complaints to management masked some of the benefits and led to lost credibility in certain circumstances. Usually these situations were cleared up when senior management intervened to solve a problem. At one such time, the cause of the problem was identified to be a deficiency that had already been identified, but could not be remedied because of the re-allocation of system resources by management.

5.8. CDO SUMMARY

Using the Case Description Outline(CDO) prepared in Chapter 4, the corresponding detailed observations have been prepared and are detailed in Appendix B1.

The purpose of the case evaluation was defined to be the testing of the hypotheses.

The specific research hypotheses to be tested are:

H5: The use of DSS technologies results in successful GMI scheduling systems.

H6: The use of Expert Systems Technologies results in successful GMI scheduling systems.

H7: The merging of DSS and ES technologies(DSS/ES) results in successful Garment Industry Scheduling Systems.

The Case I hypothesis testing is conducted as follows:

1. Using the CDO; is the case an example of a DSS, ES or DSS/ES system ?

   The Setting: The intent of the project was to solve a scheduling problem by providing a DSS for the scheduler.

   Design methodology: The DSS development focused on the Scheduler, employed rapid prototyping, and evolved structure.

   Design Representation: The system developed contained many of the characteristics of a DSS.

   Therefore, the case is an example of a DSS.

2. **If it is, then, did the case result in a successful GMI scheduling system ?**

   Results: The resulting system was a success, in that it was used, valued, and seen to be useful by management.

3. **If it did, then, which specific technology characteristics contributed to the success, and how ?**

   Success was achieved as a result of several factors:

   1. Development focus on the capable, high profile scheduler.
   2. Management support for the project, budget, and allocation of staff over the initial 24 months.

3. Capable system development team, with appropriate software and hardware for prototyping.

4. **From #1, if the case was not an example of a DSS, ES or DSS/ES, then, why was it not, and did these differences contribute to success or failure?**

   Not applicable.

5. **From #2, if the case did not result in a successful system, then why did it not, and do these reasons support the accepted wisdom of the relevant technologies ?**

   Not Applicable.

In conclusion, Case I supports the hypothesis

H5: The use of DSS technologies results in successful GMI scheduling systems.

Hypotheses H6: and H7: are not supported since the system was not developed as an Expert System, nor contained any ES concepts.

CHAPTER 6 - CASE II: SCHEDULING SYSTEM PROJECT II

6.1. RELEVANCE TO THE STUDY:

In my initial draft of the thesis I did not plan on including this case. It was not until I had redefined the more precise hypothesis and focus for the study that I realized that, not only was this case important in the hypothesis testing process, but its value as a failed project is significant to future researchers and practitioners. In this respect, I have given the case almost the same status as the other two, which are considerably longer.

The events of this case occurred after Case I was completed. The Case III project had started but was still in the early stages of developing a prototype when this case began. The calendar below indicates the approximate timing of each case.

	1983	1984	1985	1986	1987	1988	1989	1990
Case I	**	****	****	****	**			
Case II						**	**	
Case III					**	****	****	****

6.2. ROLE OF THE RESEARCHER/RULES OF EVIDENCE

My involvement in this project was as an external consultant who was retained to review the current scheduling systems, recommend new systems and if approved, develop and install such systems. Unlike Case I where I had an office and spent considerable time on several projects within the company, in this project I spent an average of 10 hours a week at the Case II company offices. This meant that specific meetings were always planned. Each meeting had an agenda, informal minutes taken, often in my journal, and conclusions or meeting decisions documented. Periodic letters and reports describing conclusions, recommendations, or decision points were presented.

A clear record of my time and activity, was necessary since weekly time sheets were submitted with each invoice. Since one of the results of the project was a Lotus 1-2-3 system, many printouts of the interim and final system were placed in the files. These files and records, from which this case has been recreated, provide a clear depiction of the chronology and content of the events and results of the project. These records are described in Figure 6.1, Case II Documentation.

In recreating the project, in the case format, many of the meetings, major encounters, breakthroughs and frustrations have been re-lived as if they occurred yesterday. I have also been assisted by recent discussions with the person who was the General Manager during the case period.

Thus it is with confidence that I have documented this case and I believe it to be an accurate and factual reproduction of the major events and results of this project. The interpretation of the results, however, I attribute only to myself. As with the other two cases, reflection of the facts of the project has been a rewarding and illuminating experience.

The CDO for the case is appended as Appendix B2. The CDO was a useful guide to identify the important observations of the case.

Figure 6.1.
Case II Documentation

Period	Document	Content
06/01/88	Proposal	Terms of Reference, Phases, goals, etc
06/88-05/89	Weekly Time sheets	Date,hours spent, names location, brief agenda
06/88-05/89	Daily journal	Date, names, agenda, notes(minutes, results, concepts, musings, etc)
06/88-05/89	Report samples	Copies of manual system forms, reports, & notes.
06/88-12/88	1-2-3 Reports	Copies of new system reports & notes.
06/16/88	Scheduling Review Report	Observations, Conclusions and Recommendations of the review.
06/17/88	Consult-1 Invoice	Consultant-1's time sheet for assistance on June 10, 13, 15.
08/26/88	Consultant-1 Report	Report for developing a Cutting SAM/UNIT chart.
08/15/88	Advertising brochure	Summary of system scope, features and worksheets.
09/17/88	Letter to G.M.	Report on Cutting SAM/UNIT chart and PC recommendation.
10/19/88	Meeting announcement	Memo of Oct 24th Scheduling Committee Meeting
10/24/88	Meeting Agenda	List of topics and schematic system drawing
05/05/89	Letter & report	Concluding report to President

6.3. THE SETTING

In June 1988 I was telephoned on a Sunday night by a garment industry consultant whom I had known for a few years. In an urgent voice, he implored me to meet him early Monday morning to discuss a serious scheduling problem with a major client.

I was now 9 months into the development of the Lisp prototype of the Expert Scheduling System project with the Case III company, and eager to test the new concepts in another situation.

On Monday morning, the consultant arrived at my office and began to explain to me some of the problems that. to him, seemed to indicate that a scheduling solution was needed.

After meeting for one hour I understood the situation to be as follows:

The Case II company was in the midst of their ladies coat production for the Fall(and winter) season. Deliveries were promised for August and September and the General Manager and the President were unable to determine if this schedule could be met.

At the same time, the Cutting Department Supervisor was totally frustrated with the excessive demands that were being placed on him. The Product Manager in charge of the Coats Division was unable to determine if fabric orders were sufficient to meet the projected and confirmed sales, and if the expected arrival date of fabric shipments would precede the availability of production capacity.

The consultant further described to me that the working environment had become very stressful caused by, in his opinion, the uncertainty and frustration of the various key players.

According to the consultant, the situation was critical for the company. If the Fall shipping period did not go well for the company, restructuring would be required.

With this background a meeting was arranged with the President and General Manager two days later. I prepared a one page outline of the terms of reference for the proposed work.

Specifically I proposed a three phase study as follows:

1. Scheduling Systems Review of the existing scheduling related systems, including recommendations of appropriate systems, computer hardware and software.
2. Conditional upon Phase 1.,and the acceptance of recommendations, Phase 2 would develop such systems, and train the staff.
3. Phase 3 was to provide operational assistance in identifying schedule problems and evaluating solutions options.

Two days later at 10:00 AM the consultant and I met at the plant of the coat company. We were led to the President's office where the discussion began on how the consultant believed I could help with the scheduling problems. The President called in the General Manager and then described his version of the problem. In his mind, the key information that was missing was the schedule of when and how much of each fabric was needed to produce the confirmed sales orders. He related that, historically, the company had always had the problem of too much of the wrong type of fabric in the warehouse at the wrong time, and none of the required fabrics when the production was scheduled.

I referred to my experience as Chairman of the Case I company Scheduling Committee and indicated that this problem had been overcome by weekly meetings focused on clear reports of fabric delivery plans and production schedules. The President instructed the General Manager to finalize the terms and we closed the meeting.

Thus began a third scheduling project. One that was to last eleven months and would provide an excellent testbed for further refining many aspects of the design, development and implementation of automated scheduling systems.

6.4. THE DEVELOPMENT OF THE DSS

On June 7, 1988, I arrived for the first day of the project. As agreed my first meeting was with the General Manager(GM), who described the organization of the company, who the key managers were and their responsibilities. These were:

Coats Division - Purchasing/Product Manager

Cutting Dept Manager

Production Manager for Sewing, and Finishing

Distribution Supervisor

Computer Systems Manager

We discussed the general flow of my review and the need for me to meet and review the operations of each of these areas.

I was led to another office that was used by the auditors for two months of the year and otherwise as a storage area. The GM said he would have the office cleaned up and this would be my work area.

We then proceeded to each of the key managers areas where I was introduced. I arranged meeting times with each manager.

After my first set of meetings I reviewed my progress with the consultant who had introduced me to this situation. As we discussed the personalities and problems we soon became aware that his prior conclusions and my current observations were consistent.

He stated that in past management meetings that he had attended, when the topic of late customer deliveries arose, each key manager alternately defended their situation and indicated that the cause of their problems or uncertainty originated in another area of the company.

I had found that my discussions with the managers on their problems led to the identification of the lack of correct information, or the late flow of goods from the previous department, as being the causes of each area's problems.

As presented to me, the Cutting department had to lay-off staff in one week and then re-hire two weeks later because they had with more work then they could possibly cut in 4 weeks. The Sewing Production Manager claimed he needed faster throughput from Cutting so he could keep all his staff working. The Product Manager was totally frustrated with the current MRP system since the Fabric Requirements Report was "wrong" and could not be used. The Systems Department Manager indicated that he was unaware that the Fabric Requirement Report was incorrect. These problem inter-relationships are depicted in Figure 6.2.

Figure 6.2

Problem Inter-Relationships

Product Manager:

1. Sales Forecasts are too general to use as base to commit fabric purchases.
2. Sales Orders slow arriving into the office.
3. Fabric Requirements Report only reflects confirmed orders, not "telephoned salesperson orders", or forecasts.
4. Fabric Mills require long lead times to produce, ship and deliver.
5. Fabric Deliveries are seldom on time, have wide variance and often have large quantities short shipped and back-ordered.

Cutting Manager:

1. Flow of Cutting Orders from Product Manager is uneven, either too much work or not enough.
2. Insufficient lead time of planned Cutting Orders to allow for proper staff planning to handle peaks and valleys.

Production Manager(Sewing, Finishing):

1. Flow of work from Cutting is uneven, resulting in the need for large Work-in-Process inventories in sewing to keep all sewing operators busy.

Warehouse/Shipping Supervisor - Product Manager is responsible.

1. Flow of completed Cuts is uneven, seems to peak at month end since most deliveries for a given month can be sent as late as the end of the month.
2. Computer system does not clearly show the Order Status information; i.e. Delivery date, shipped, to be shipped. Available-to-ship inventory(from completed cuts) is slow being updated and the Allocation of Finished Inventory is a manual process. Thus actual shipping is not updated until goods have left warehouse and have been invoiced.

In recent weeks, the General Manager had been holding frequent emergency meetings, which were being cited by the other managers as the cause of them having insufficient time to do their work. At the same time the domineering President was on a rampage and had the managers fearful for their jobs.

As the gravity of the situation became clear I wondered what I had got myself into this time.

Over the next seven months I met often with these managers and spent considerable time in each area of the company. The detailed activities , time periods, and results are presented in Figure 6.3.

Figure 6.3

Summary of Main Activities

	TIME PERIOD	ACTIVITIES	CONCLUSIONS
A.	Pre-June'88	Manual Scheduling carried out as part of Product Manager's responsibilities. Scheduling ordering Fabric, writing Cutting Orders, Loading Production and co-ordinating Warehouse Shipping.	Lack of timely and accurate information leads to uncertainty of achieving delivery dates.
B.	June'88	President requests help from Consultant #1, who invites researcher(me), to discuss project.	Scheduling System Review is proposed and approved.
		Scheduling Review conducted by me. Recommendation for new scheduling system to clearly identify capacity and potential delivery problems.	Researcher begin development of Lotus System to integrate Cutting, Sewing, Finishing, and Shipping Schedules.
		Report recommends full time scheduler.	General Manager(GM) approves position
C.	July'88	New Scheduler hired-has experience in in basic production scheduling, and Lotus. Scheduler is husband of GM's assistant.	Scheduler known by GM and managers. Appears to be a good choice for the job.
D.	July'88	Scheduler and researcher given storage room/office to work in. Old PC Clone given to Scheduler. Researcher uses his portable Toshiba 3200.	Researcher requests latest version of Lotus.
		Scheduler begins intensive study of company systems.	Scheduler learns quickly.
		New Version of Lotus obtained.	Scheduler studies Lotus.
		Researcher develops initial worksheets and gives to Scheduler to begin orientation.	Old PC clone is too slow.
		Scheduler begins to collect detailed scheduling data(capacity, Style SAMS,etc) SAMS=Standard Allowed Minutes, used for piece work and costing.	Cutting dept SAMA are seen to be a poor measure of actual work required in Cutting dept.

Figure 6.3 continued

E. August'88	Researcher recommends that Consultant #1 study better methods of assessing Cutting Dept SAMS.	Consultant #1 conducts detailed analysis of Cutting work units.
	Consultant #1 develops Cutting SAMS chart based on type of garment and number of units in the cut.	Excellent work by Consultant #1.
	Scheduler assigned to assist Shipping Dept. on a part time basis.	Scheduler develops a Lotus Inventory Report to assist Warehouse manager.
	Scheduler assigned to supervise the Year-End Inventory counting at end of August.	
	Researcher and Scheduler recommend purchase of new "386 PC for Scheduling.	Recommendation approved. Portable Compaq'386 purchased. Scheduler now has good tools.
F. Sept'88	Researcher completes scheduling system. Reviews with GM and Managers. Scheduler trained.	Concept is complex but understandable. GM surprised at how much data is needed.
	Scheduler begins using system to schedule fall production of Coats Division, for delivery in Jan'89.	Researcher checks on status. Progress is good.
	Scheuler begins daily collection of relevant information from all departments: - sales and new forecasts, - fabric orders and deliveries, - new Cutting Orders, - Cuts started in each dept. - completed Cuts from each dept. - capacity plans	Scheduler creates forms and simple procedures to obtain required information form each dept. Scheduler reports to GM that system appears to be useable.
	GM wants system to be used for Sportswear and Suits divisions as soon as possible.	

Figure 6.3 continued

October'88	Scheduler still deeply involved in the reconciliation of the Year-End inventory count.	Main MRP system does not address real needs of operations. It's value is only for Orders, Invoicing, and Accounts Receivable.
	Scheduler develops a new Stock List worksheet for weekly update of stock available for sale.	Scheduler says he can do both jobs.
	Company buys a small plant. GM wants plant put on schedule.	Scheduler may not have enough time.
	Scheduler takes portable home most nights and on weekends.	
	First "Weekly Scheduling" meeting held with GM & managers. System with current data presented	Several interruptions during meeting. President walks in and listens then leaves.
	Managers must have summary control totals to compare with their existing manual systems.	System must be modified to allow easy comprison with existing manual procedures now operated by each dept manager. Unless totals are the same system is not credible.
	Managers understand system, and agree to work with Scheduler when fabric is ordered and cuts are written	
	Purchaser asks me to join her in meeting with President. He emphasizes that system show fabric requirements by date and quantity.	It seemed odd that GM was not invited also.
	System is enhanced to take capacity schedule and extend units loaded by week to fabric type and qnty required by week.	President's involvement has resulted in a very useful extension of the system.
November'88	Scheduler is to call another Weekly Meeting, but is not ready. Scheduler indicates he has almost completed the Year-end inventory count process and then will have more time. Scheduler is pressured to maintain weekly Stock List for Sales dept.	The poor scheduler seems to have gained a reputation for developing and running useful information systems. Both Warehouse and Sales depts now rely on him.
	Second Weekly Scheduling Meeting held 1 month after first. System shows deliveries for Dec'88 and Jan'89 will be late. GM and managers are stunned. Some discussion follows but no decisions or actions result. Next meeting planned in 2 weeks.	Situation seems confused; is the system right? what should be done? who is responsible? Decision is to do nothing.

Figure 6.3 continued

I. December'88	Meeting is postponed the next week. GM must travel to China. I call Scheduler, then GM to determine planned action. Scheduler is still maintaining system.	Without GM, managers do not want to meet.
	In late December Scheduler tells me that he has resigned. System usage ceases. System is reviewed with Controller before Scheduler leaves.	
J. January'89	New Scheduler hired at the end of January - has many years of garment engineering experience. No prior PC experience.	Main aptitude is production engineering. Not a good PC user.
K. February'89	New Scheduler decides to review all systems first. He determines that information flow to the Scheduler must be "systemitized", with forms and procedures.	Orientation and training will require months. Fear of system may be causing Scheduler to find other tasks.
	GM and President realize that deliveries are late and that next season will be worse. President buys another plant.	Late deliveries predicted by system in November were correct.
	GM requests Scheduler to evaluate the new plants. Scheduler cannot use the scheduling system so must do analysis manually.	This is exactly what the Scheduling system does best.
	Scheduler calls me for help. Scheduler can do one analysis on one manual spreadsheet per day. With the Scheduling system, a good scheduler analyse 20-30 options per day.	What scheduler does in one month, could be done in 1 day.
L. March'88	GM asks Scheuler to become involved in the Merchandising Calander System. Scheduler is soon given full responsibility for the Calander system.	No apparent plans to use the system.
M. April'88	Scheduling Project Budget has been exhausted. I prepare a final report for the President.	No response. End of Project.

6.5 THE RESULTS

Using the Case Description Outline(CDO) prepared in Chapter 4, the corresponding detailed observations have been prepared and are detailed in Appendix B2.

The purpose of the case evaluation was defined to be the testing of the hypotheses.

The specific research hypotheses to be tested are:

H5: The use of DSS technologies results in successful GMI scheduling systems.

H6: The use of Expert Systems Technologies results in successful GMI scheduling systems.

H7: The merging of DSS and ES technologies(DSS/ES) results in successful Garment Industry Scheduling Systems.

The Case II hypothesis testing is conducted as follows:

1. **Using the CDO; is the case an example of a DSS, ES or DSS/ES system ?**

   The Setting: The intent of the project was to solve a scheduling problem by providing a system based on the Case I DSS.

   Design methodology: Although the Case II system was based on many of the model concepts of Case I, there were several aspects of the methodology that did not follow accepted practice of DSS methodology.

   Design Representation: The system developed contained many of the characteristics of a DSS.

2. **If it is, then, did the case result in a successful GMI scheduling system ?**

   Results: The resulting system was a failure.

3. **If it did, then, which specific technology**

characteristics contributed to the success, and how ?

Not applicable

4. **From #1, if the case was not an example of a DSS, ES or DSS/ES, then, why was it not, and did these differences contribute to success or failure?**

The system was not a DSS.

Although the system was intended to be a DSS, it did not adhere to many of the accepted practices of successful DSS and general Information Technology projects.

The most obvious deficiencies were:

1. Absence of a capable, high profile scheduler.
2. Insufficient management support.

Did these differences contribute to success or failure?

In my judgement, the differences did contribute to the failure of the DSS.

5. **From #2, if the case did not result in a successful system, then why did it not, and do these reasons support the accepted wisdom of the relevant technologies ?**

Many of the reasons for failure can be traced to the deficiencies that are described in the accepted wisdom of the DSS technology. Specifically, the requirements for project success were not present and failure was indicated.

6.6 CONCLUSIONS RESULTING FROM FAILURE

The analysis of the failure of this project has led me to define several questions, namely;

1. Was there a key event or turning point that can be singled out as the divergence that led to failure?
2. Was there a general deficiency or set of deficiencies that were present from the start, and was it just a matter of time before the deficiency became dominant?

If the answer to either of these questions is positive then my next questions are:

From #1:

1.1 How can these key events or turning points be identified?

1.2 Are the turning points dependent on the application and industry?

1.3 What is the correct response once the key event or turning point is identified?

From #2:

2.1. Could the deficiency or set of deficiencies be identified by a checklist instrument with a threshold that would signify the likelihood of failure?

Although there are many additional questions that are relevant to this discussion, and to do justice to these 6 would entail a separate study, I have attempted below to provide my answers based on this Case.

1. Key Events and Turning Points:

In retrospect, the following events signified potential problems for the project:

1. The assignment of the scheduler to assist with the year-end inventory count.
2. At the end of the year-end count project, the re-

assignment of the scheduler to the maintenance of the stock list.

3. The resignation of the scheduler was the event that can most easily be identified as the turning point.

While events 1 and 2 do not seem to be of the magnitude of 3., they were tendencies that signify potential time allocation problems. They may have contributed to the resignation of the scheduler.

Another scenario that, in retrospect, foretold of a problem was the difficulty in arranging Weekly Scheduling Committee Meetings. Only two out of a potential of over twelve were held before the scheduler's resignation was announced. This situation was caused by a combination of the scheduler being unable to prepare for each week and the General Manager and middle managers being unavailable. Their unavailability may have been caused by either the pressures of their workload or their lack of motivation. Although the scheduler appeared to be able to obtain the co-operation of these managers, their resistance or lack of support may have been a factor in his resignation.

1.1 How can these key events or turning points be identified?

In pondering this question, I recollect that I did in fact realize that these events did signify potential problems and I did bring them to the attention of both the scheduler and the GM. While both acknowledged their importance, they assured me that they would not be a problem. Another key event that now seems relevant was the business trip that the GM took to China in mid October 1988. This was to be a 2 weeks trip, however he did not return for 5 weeks. Upon his return he continued to be emersed in the China project. The lack of his direct involvement allowed the middle managers to reduce their support for the scheduling project and the weekly meetings.

1.2 Are the turning points dependent on the application and industry?

The GMI is a dynamic environment, especially because of the seasonal focus and the importance of the main activities in the seasonal calendar(i.e. Style design, Selling period, fabric purchasing period, production period, shipping period). The re-allocation of the scheduler's time to an immediate emergency and the GM's trip to China are indicative of the priority given to operational priorities. The operational pressures felt by the middle managers were much more important to them then a scheduling project, that in the short term required extra time, and, in the long term, may have threatened the status quo.

1.3 What is the correct response once the key event or turning point is identified?

I believe this project could have been successful. The scheduler was making progress and, as experienced in Case I, by operating the system over 2 seasons, and demonstrating the system's accuracy, power, and value, its credibility likely would have been accepted. While the resignation of the scheduler was the major negative event, if an appropriate replacement had been obtained, in time the DSS would have succeed in providing at least as much value as the DSS in Case I.

The fact that the urgency of operational problems contributed to the re-allocation of the scheduler, the lack of motivation for the middle managers and the absence of the GM, may, in retrospect, have been overcome by the presence of a persistent, strong willed, enthusiastic and competent scheduler, of the type that existed in Case I. Regretfully, such a person was not found.

2. Deficiencies:

2.1. Could the deficiency or set of deficiencies be identified by a checklist instrument with a threshold that would signify the likelihood of failure?

Perhaps such a checklist could be produced, and in time, likely would evolve to a workable instrument. As a starting point the lessons of this case would suggest the following checkpoints:

1. Does the Company have a capable, high profile scheduler with ample time to work on the project ?
2. What are management's expectations and level of commitment in the areas of:
    a. Project Time to initial version,
    b. Budget, time and cost
    c. Staff availability: Scheduler, managers, systems staff,

3. What is the company's management style:

   a. Chaotic, undisciplined, reactionary

   b. Operationally oriented,

   c. Planning oriented

   d. Major successful projects completed recently.

4. Meeting attendance history and experience.

The answers to these initial questions would likely have alerted me to the potential for the occurrence of the problems that eventually developed. Upon reflection, had I known of these problems and had I brought these to the attention of the General Manager or President, I doubt that the likelihood of success would have increased. The management style of short term reaction to operational emergencies would have eventually dominated the scheduling project, regardless of prior warnings. It would seem some project are better left on the shelf, if the management style is not appropriate.

CHAPTER 7 - CASE III: SCHEDULING SYSTEM PROJECT III

7.1. RELEVANCE OF THE STUDY

This case is important to this study for the following reasons:

1. From a GMI perspective, the case traces the events and activities that created one of the first expert scheduling systems in the garment industry(Sawatzky and Peterson 1990).
2. From a DSS perspective, this case describes the study of an expert scheduler as a decision maker and the types of DSS tools he needs to increase his productivity.
3. The goal of this project was to study the application of expert systems(ES) technology to the GMI scheduling problem. Thus from an ES viewpoint, this project describes the application of accepted ES methodology towards the development of a system that possesses many characteristics of an expert system and advances the knowledge of ES technology applied to the scheduling function.
4. From a research viewpoint, the environment and key players provided an exceptionally positive and well controlled environment for testing the Hypothesis that ES technology can be applied successfully to the GMI scheduling problem, and identifying the success factors.
5. From a personal view, this case has been extremely gratifying both as a successful research project, and as a significant contribution to the GMI. The scheduling system described in this case has also been

recognized as one of only a few expert scheduling systems in full operation today(Sawatzky & Peterson 1990).

The calendar below indicates the approximate timing of this and the other two cases.

	1983	1984	1985	1986	1987	1988	1989	1990
Case I	**	****	****	****	**			
Case II						**	**	
Case III					**	****	****	****

7.2. ROLE OF THE RESEARCHER

My involvement with this company began in mid 1987. At the time I was into my third year of the Ph.D research and had determined from Case I and my literature search that a worthy goal would be to attempt to create an expert scheduling system for the GMI.

During the period mid 1987 until the present I have been the principal analyst, designer, architect and researcher for this case and the resulting system. Throughout this period I was assisted by several knowledgeable and talented schedulers, analysts, developers and business associates, without whom I would not have been able to conduct any of the activities described in the case.

At the time I initiated the research project that eventually led to a successful operating scheduling system I was viewed in the garment industry as a knowledgeable consultant who was studying the application of AI technology to the GMI.

Without being pretentious, I had established my credibility within the local AI community, including the

Canadian National Research Council(NRC). The NRC had recently opened a new research facility as an incubator for the application of new technologies to the manufacturing industry. I was encouraged to apply for a subsidized project to commercialize my research. This application was successful, and this project began.

During the period described in this case(1987-1991), my roles were:

1. Project leader, chief researcher, knowledge engineer and designer of the many versions of the Scheduling system described in this case.
2. Team member, with an Expert Scheduler form the Case III company, and a knowledge engineer from the NRC, and later two senior analyst/programmers.
3. President of Strategic Innovations Inc, the company that became the Research Partner with the NRC.
4. President and co-owner of CAASS Inc., the company formed to develop the Delivery System version of the scheduling system.

7.3. PROJECT PHASES

The project can be divided into the following phases illustrated in Figure 7.1. Phase I was undertaken to determine if Expert Systems technology could be applied successfully to the GMI. The general methodology employed was to create a prototype (Phase I) to demonstrate the viability of the technology, to prove the concepts, and to define the system requirements and design directions. The commencement of Phase II was to begin when and if Phase I was successful. The success of Phase I was not precisely defined, since our team did not know what the prototype would look like, nor what it would do. We did know that the criteria for success was closely linked to the acceptance by the schedulers in the GMI and this became our target. We also realized that the acceptance of the schedulers would correspond to levels of functionality, system performance, and useability, within acceptable cost.

Figure 7.1

Case III: Project Phases		
	Phase I	Phase II
Phase	ES Prototype Development	ESS Delivery System
Team Members	NRC-K.E. Analyst-1 VP Manuf.	Analyst-2 Investor
Location	NRC office	CAASS Office
Period	09/87-01/89	01/89-07/90
Documentation Methods	Marker Board Flip Chart DEC-VAX WP File folders	Flip Chart MAC II MS/WORD File Folders
Development Equipment	DEC-VAX DEC-PC Symbolics MAC-II	MAC II
Development Software	ART, LISP, KEE, Pascal MAC II/OS	MAC II/OS Pascal

7.4. RULES OF EVIDENCE

As a researcher, knowledge engineer and system developer, I was continually aware of the need to document and to retain detailed records of the events and related documentation. The NRC Knowledge Engineer, was equally motivated to document every step, observation, conclusion and output from our project. Consequently, the documentation of this project is extensive and as near complete as I could imagine.

The working environment was as close to ideal as I could imagine. My office was the project office and meeting room. The purpose of the office was to conduct this research and I furnished it with a large white marker board, a flip chart, a meeting table, that also served as my desk, four comfortable meeting chairs, a few plants, and a filing cabinet. The NRC provided a DEC PC connected to the a large VAX cluster with the latest in AI languages and office productivity software, the DEC ALL-IN-One package.

The project office became the focal point for the meetings and knowledge acquisition sessions that were held. There were seldom any interruptions and lengthy meetings would pass, seemingly in seconds, as we became deeply engrossed in the creative searching process.

Our primary methods of documentation were the flip chart and the DEC ALL-IN-One word processor. Our file folders held the many exhibits including: sample documents, scheduling related materials, computer listings and progress reports, meeting reports, articles, and external information. and rough notes that we accumulated in our visits to the Case III company. I maintained a separate set of files relating to the formal NRC interactions, including periodic progress reports and related letters.

I continued to retain a daily journal, however, my entries were limited to meeting times, brief objectives, and any action required by me. Unlike Cases I and II, there was no need to retain detailed time sheets.

These files and records, from which this case has been recreated, provided a clear depiction of the chronology and content of the events and results of the project. These records are described in Figure 7.2, Case III Documentation.

The recording of the major events and activities of this case was not difficult since we had excellent working documents and records. As with Case I, the most difficult aspect of describing the three year period researched in this case has been to limit the amount of description. As before I have used summarized tables to attempt to succinctly describe the relevant main events of this case. Thus it is with guarded confidence that I have documented this case and I believe it to be an accurate and factual reproduction of the major relevant events and results of this project. The interpretation of the results, I attribute only to myself. As with the other two cases, reflection of the facts of the project has been a rewarding and illuminating experience.

In this Case, even more so then the others, I was Brewer's(1981) "change agent". Unlike his situation I was the researcher, working in my laboratory, as it were, to apply a prototyping methodology espoused by prior researchers and practitioners such as Barr &

Feigenbaum(1981), Feigenbaum(1988), O'Farrell(1986), Hayes-Roth(1983), and Harmon and King(1985), to a problem not yet studied in the GMI.

As he found in his research, being both an internal change agent and a researcher, involves the necessity of retrospective reflection, the accumulation of copious notes, and consideration of their use at specific points in time in order to ensure that the trends and events can be seen in the context of a research study.

I believe, as Bennett (1986) cited, the importance of case study research is that of exploration with the intent of attempting to identify the potential existence of relationships, and phenomena that eventually may lead to more empirical research with the eventual formulation of broad based theories and appropriate methodologies.

The Case Description Outline(CDO) for the case is appended as Appendix B3. The CDO was a useful guide to identify the important observations of the case.

Figure 7.2
Case III Documentation

Period	Document	Content
07/87	NRC Research Application	Proposal for conducting ES research to GMI Scheduling.
08/87-06/89		
	Flip Chart pages	Date, names, agenda 20 sets x 30 pages
Observations, analyses		
		model concepts, tables, conclusions, report notes plans, milestones, goals, display designs,
08/87-07/90		
	Daily journal	Date, names, agenda, brief notes and ToDo's
08/87-06/89		
	WP-documents	Word Processing documents of meeting reports, field trip observations, interim progress reports.

Figure 7.2 continued

Period	Document	Content
06/89-07/90	Meeting reports	Weekly management meetings held by the CAASS mngt team. with supporting documents,and meeting minutes.
01/88-06/89	Computer listings	Lisp, ART and KEE program listings of the versions of the prototype and early delivery versions of the ESS.
01/89-01/91	Computer Listings	Pascal program listings of the Delivery system, called CAASS Version 1.0 to 1.4.
09/87-09/90	Bobbin Show Trip Reports	Reports of the 1987, 88, 89 and 90 Bobbin Shows.
10/89	Conference Paper	Paper delivered to the Fourth Annual Conference on Expert Systems in Production and Operations Management, Hilton Head, S.C, May 14-16, 1990. (see Appendix C).
06/90	Conference Report	Report on the Fourth Annual Conference on Expert Systems in Production and Operations Management, Hilton Head, S.C, May 14-16, 1990.
07/87-09/90	File Folders	Field notes, Case II co. documents and photocopies of operational documents, articles, and rough notes.
09/89-09/90	CAASS User Manual	User's Manual for the CAASS system, latest version 1.4
02/90	Report on CAASS by H. Vose.	Article on CAASS system as used by Sterling Stall. (Appendix C)
07/90-01/91	CAASS literature	Sample CAASS descriptive literature. (Appendix D)

7.5 THE SETTING

One of the goals of management research is to put research to work(Bennett 1986). The opportunity for me to begin such a task was afforded to me by the National Research Council(NRC) of Canada. In 1987 the NRC opened a new manufacturing research facility in Winnipeg, Manitoba.

This facility was heralded with much political fanfare as the NRC's centre for the advancement of new manufacturing technologies. By mid 1987 the NRC's new Canadian Institute of Industrial Technology(CIIT) was requesting proposals for "research partners" to rent the crisp new offices and obtain assistance from the resident NRC research staff.

One of the first focuses for the CIIT was Artificial Intelligence. As a co-founder of the A.I Society of Manitoba, I was invited to participate in this new centre.

By late 1987, while in the midst of the write-up of Case I, Strategic Innovations Inc. become a research partner. The project staff consisted of myself and 50% of a junior knowledge engineer from NRC assigned to a project entitled " The Commercialization of Scheduling Research in the Garment Industry". The agreement between the NRC and SII referred specifically to my Ph.D. research into scheduling, as the basis for the project.

From late 1987 until mid 1989 SII and the NRC partnership advanced the scheduling research from concept to a working prototype written in LISP. This prototyping project began in late 1987 with the involvement of another major garment manufacturing company, The Sterling Stall Group(SSG). The Vice President of Manufacturing at SSG had previously been a consultant to Tan Jay during the period

1984-1986 when I had been developing the original scheduling DSS reported upon in Case I.

Recognizing the enrichment from working with another company I presented the opportunity to the Vice President over lunch in late 1987. For no obligation on the part of SSG, except for the time of the V.P. and access to his company's operations as a research site, SSI and the NRC would attempt to develop an Expert Scheduling System(ESS). If the project was successful SSG would be granted a license to use the software in their own plants.

Thus the project began with a V.P of Manufacturing as our Scheduling Expert, the NRC analyst as a knowledge engineer programmer and I as the project leader/knowledge engineer/scheduling researcher. In the period January 1988 to January 1989, working an average of 40 combined hours per week, including 2 meetings per week, this team was able to achieve the development of the ESS prototype, written in LISP and operational on a Macintosh IIc computer.

7.6 THE DEVELOPMENT

7.6.1. The Prototype Development:

The prototyping project was described in a paper written by G. Sawatsky and J.Peterson(1990) entitled "Application of Expert Systems in Capacity Planning for Garment Manufacturers". I presented this paper to the Fourth International Conference on Expert Systems in Production and Operations Management, May 1990, Hilton Head, South Carolina. This paper is appended as Appendix C.

The detailed events and activities that occurred during the prototype development are presented in Figure 7.3.

Figure 7.3
Case III Events and Activities
Prototype Development

	TIME PERIOD	ACTIVITIES	CONCLUSIONS
A.	Aug'87-Oct'87	Project initiation with NRC and SSG.	An exceptional opportunity.
		NRC analyst begins study of draft Ph.D thesis.	No prior manufacturing experience is a major difficulty.
B.	Nov'87	Project meeting begin (2 per week)	Level/Plateau of Comfort" processes repeated until the collective understanding of all is at the first plateau.
		Detailed Scheduling analysis. Education of VP into prototyping. Education of NRC into scheduling. Selection of ART on the VAX 780 made to begin prototyping.	
C.	Dec'87	First step is to design MRP MRP database in LISP/ART.	Some Knowledge elements added to the MRP database as per "Shadow" Kbase concepts.
		Simple "Proof of Concept" goals are defined. Goal 1-load orders.	Scheduler manual tools are primitive. Paper, pencil and eraser. Gross approximations must be made. Drastic errors are made.
D.	Jan'88	NRC completes first version of Lisp Database on VAX.	The project can move only as fast as the programmer can implement the new concepts.
		NRC completes first goal of automatic loading of simple orders.	First breakthrough. Very encouraging. 30 orders are loaded in .1 second. Next "Level/Plateau of Comfort" has been achieved. Enhancement ideas flow
		Obvious real inconsistancies are addressed.	quickly place the "Auto-Load" tool in the correct context.
E.	Feb'88	Changes/enhancements are made.	VP reacts very well to being able to see current system as the base from which he can easily describe what he would like to see next.
			Ideas are coming much faster then they can be programmed.

F.	Mar'88	NRC moves development to a Symbolics AI computer with advanced graphics and mouse. Conversion and learning activities.	After a slowdown for conversion, the programmer's productivity is increased. Another Plateau of Comfort has been attained - project is ready for next thrust.
G.	Apr'88	Simple graphic concepts are identified as a possibility. Weeks, Capacity and Orders are shown as graphics on screen.	Another breakthrough - new ideas flow from the team. VP can now visualize mouse-icon concepts.
H.	May'88	Changes/enhancements are made. J.Peterson has trip planned for California-would like to take demo. How to show on Symbolics? NRC make conversion to Allegro LISP on a Macintosh IIc.	Opportunity to demo system creates a new thrust towards more common less costly platform. Deadline prompts new level of productivity. Another Plateau has been achieved.
I.	June'88	J.Peterson shows demo to show attendees-good response to basic concepts.	Encouragement, but still a long way to go to a useable system.
J.	July-Aug'88	Plan to test live data. Review of data leads to development of data entry and normal database routines.	Confirms need for integration into corporate database and basic system functions.
K.	Sept'88	Live data is used as testbed. 600 orders are loaded in 3 seconds on a Macintosh IIc.	Speed is very acceptable. Comparable manual operations would require more than 200 hours,with Lotus; 10 hours. Another Plateau has been achieved.
L.	Oct-Nov'88	Focus now on use of tool to identify and solve problems. New mouse commands needed, and different representations of time, capacity and orders.	Allegro LISP development has ceased since Apple Corp. purchased Allegro. Needed mouse and graphics functions are very difficult in Allegro Lisp.
		Minor fine tuning carried out.	Project has reached a technology block. Options assessed.
		J. Peterson contacts other Mac developers. A Comp.Sc. MSc graduate agrees to join SII in Jan'89.	

Figure 7.4
Prototype Graphical Representation

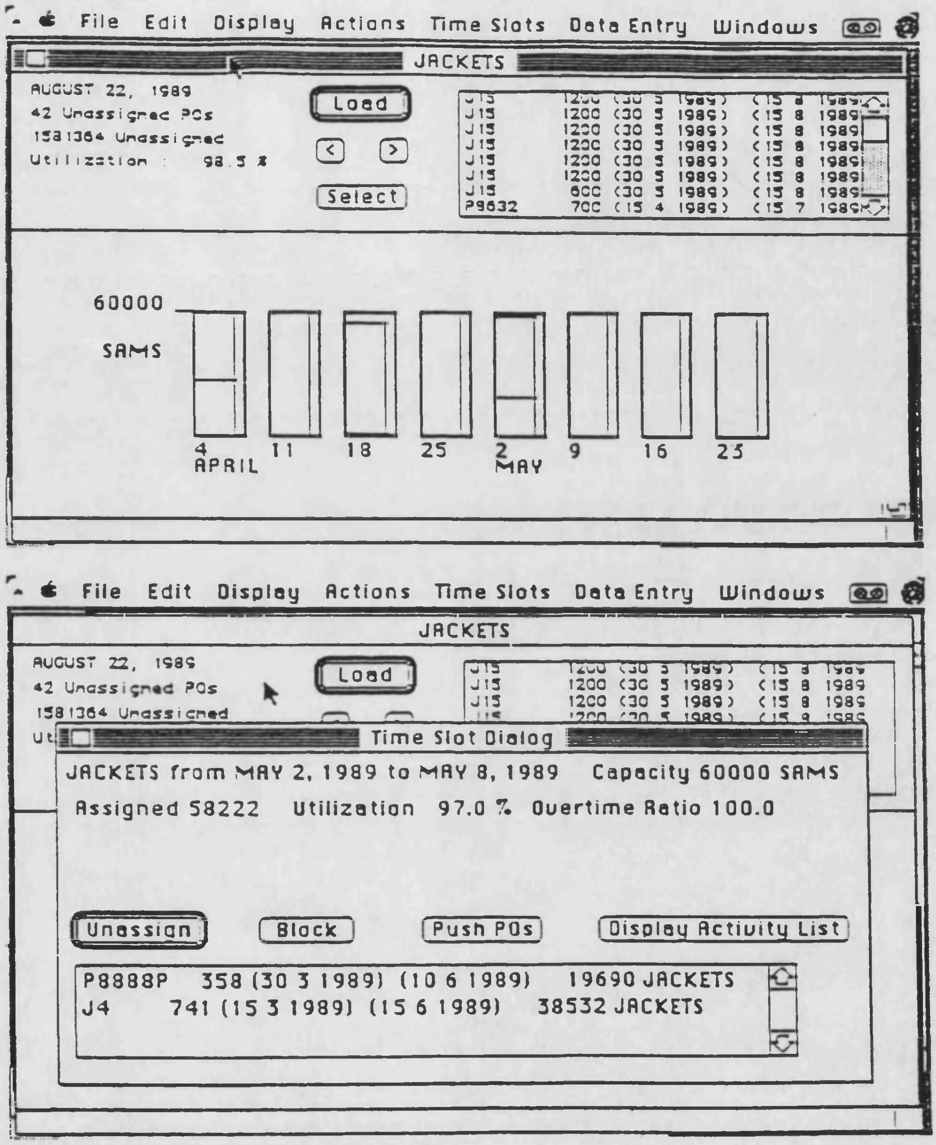


Figure 3 Sample screens from the prototype

There were several important conclusions from the prototyping project. Some of these substantiated the literature studied, others expanded it further.

In summary the following are noteworthy:

1. The project confirmed the ES prototyping methodology as a means to refine and prove the ES concepts(O'Farrell 1986). The project could also be seen as a confirmation of the DSS prototyping methodology. The distinction between, ES prototyping to prove the concept of replication of expertise with ES technology, and DSS prototyping to evolve successive versions of a DSS based on the decisions maker's processes, was often lost in Phase I. The goals of understanding the scheduler's view of the problem, how he solved or would like to solve the problem, led to the evolution of structures and representations that could be seen as both knowledge engineering and DSS design.
2. Two of the key factors described in DSS literature were confirmed, namely; the importance of the tools, and need to have the user deeply involved, were conclusions that were re-confirmed(Keen and Gambo 1983).
3. Upon reflection the prototyping project's main accomplishments were in the demonstration of the following fundamental concepts:
    1. The expert's decision process for loading orders into a production line could be represented in a Lisp program that loaded orders automatically.
    2. The representation of time as the x-axis, with arbitrary unit length selected to represent the

expert's time horizon was usable.

3. The representation of capacity as the y-axis, with arbitrary unit height, displayed a clear illustration to the user. Figure 7.4, Prototype Graphical Representation, illustrates the time, capacity and demand representations.
4. The representation of production capacity as a rectangular area(width x Height),was acceptable.
5. The representation of the required capacity of a work order as a rectangular area, with the same relative area units as the capacity of the production line, was acceptable.
6. The representation of the "production window of time" as the portion of the horizontal line segment starting at the date of fabric availability and ending at the date of customer delivery, was acceptable.
7. The clear identification of success based on the achievement of "fitting" all the demand rectangles into the capacity rectangles, transformed the problem into a "game-like process".
8. The clear identification of an unsolved problem, when some demand rectangles could not be "fitted", eliminated the tedious searching through pages of numbers.
9. The scheduler's requirement to adjust the automatically loaded schedule, if all orders could not be scheduled on time, allowed his scheduling expertise to be expressed in graphical manipulations.

10. The expert(scheduler) quickly tired of the menu and command based user interface and demanded the ability to move the work order rectangles with a mouse. This was not achievable with Allegro Lisp.
11. The representation of capacity as weekly rectangles was inadequate to represent work orders that naturally spanned week ends.
12. The feature to increase capacity in a given week, either by overtime or additional operators was a correct representation of the scheduler's decision process(analysis of options to solve the problem).
13. The structuring of the GMI scheduling problem into a representation of fitting demand rectangular areas into larger capacity rectangular areas, was promising.
14. The display of basic schedule Performance Measure information in a graphical representation was encouraged.

4. While the features that were implemented in the prototype were significant, comparison with the delivery system illustrates vividly how large the gap is between prototype and delivery system.
5. The initiation and undertaking of the prototyping project was in itself a stroke of good luck and timing. The NRC's new initiative provided the environment, staff and focus.
6. We reached a technological limitation with the use of Lisp that could not be overcome. The limitations were:
   1. the inability to represent mouse interactions, and
   2. the inability to span week-ends in continuous

capacity and demand representations.

The limitations were programming limitation of the version of Allegro Lisp available at that time.

7. The importance of this prototyping exercise cannot be over emphasized. Were it not for this project, none of the ES research concepts would have been attempted. The fact that the project proved many of the research concepts is fundamental to all the future developments related to the Delivery system.

8. The ending of the prototype project was caused by the inability to make further progress with the prototyping technology, i.e. Allegro Lisp. The occupance of this point forced our project team to search for alternate technologies and to face the decision of whether the "proof of concept", Phase I, project had in fact demonstrated sufficient functionality, and design direction to merit entering the Delivery System Phase. This assessment relied heavily upon the feedback from the VP Manufacturing of SSG and the opinion of three GMI schedulers who viewed the prototype. The decision point was forced upon us.

7.6.2. The Delivery System Development
Beyond the Prototype - the Development of a Product

One of the conclusions of the Prototyping Project was that there was sufficient functionality demonstrated in the prototype to justify an initial attempt at developing an actual Delivery system. We followed the generally accepted ES strategy of prototyping to prove the concept, followed by development of a faster, more robust, and more complete

Delivery System(O'Farrell 1986).

The events and activities of the development of the delivery system are recounted in Figure 7.5.

The decision to change technologies was forced upon us when the prototype technology was seen to be a major limitation. We began a search for another technology that had the power to overcome the prototype limitations. Upon reflection I am intrigued by the nature of determining when and how a prototyping project ends and when and how a delivery system project begins. This question I leave for future research.

In this project, the transition from Prototype to Delivery System was related to the following events:

1. The prototype developed in Allegro Lisp on the MacII could not easily be altered and expanded to overcome the design limitations. The Lisp language did not support the required level of interactive mouse graphics required to "grab": and "move" work orders, and the method of spanning week-ends was inadequate.
2. The assessment from our expert and three other garment industry associates who viewed the prototype, was very positive,
3. The strategy of prototype-to-delivery system had been planned, although neither the NRC-K.E. nor I had ever been involved in such a transition, and we had no clearly defined criteria for establishing a cut-off.
4. The NRC facilities were available for a further 7 months,
5. I unexpectedly met a very competent MAC programmer, who was looking for a new project.(I had discussed the

project with him several months previous).

In summary, the decision was to proceed with a new approach, given that the resources were available, and the motivation was sustained. Although it was our intent to develop an operational system, we were not certain if the new approach would result in another prototype or if the result would be acceptable as an operational system.

The prototype project was able to prove and demonstrate the usefulness and useability of the basic concepts and, through its limitations, many of the directions for a more comprehensive system had been specified.

The Product Development project began in January of 1989 and continued to January 1991. The main events and activities are summarized in Figure 7.5.

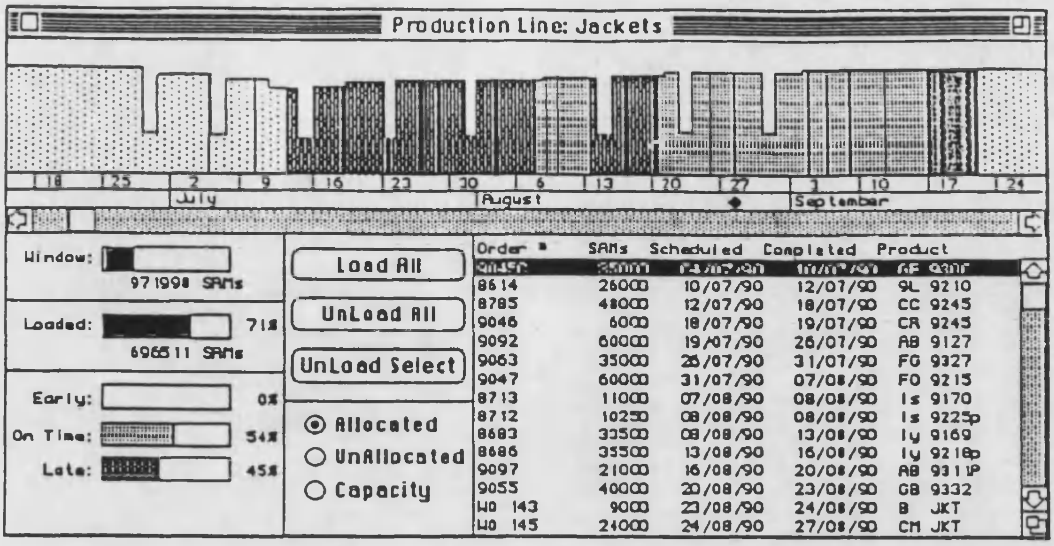
Figure 7.5
Case III Events and Activities
Delivery System Development

	TIME PERIOD	ACTIVITIES	CONCLUSIONS
A.	Jan'89	New program design begins MSc has excellent skills and is very familiar with Mac's.	
		Team meets to discuss detailed graphics features, tools, and system operations.	Another Plateau if being formed.
B.	Feb'89	Partial version of new system is ready for demo. Results are excellent.	Refinement process begins again.
		J.Peterson invites an investor to a demo of both Lisp prototype and partial ESS. Investor becomes a partner.	Demonstration of prototype and clear direction of ESS future demonstrates competence of team.
C.	Mar'89	Development continues with NRC assisting MSc. VP continues to suggest improvements after seeing current level.	Project is similar to a prototyping project, except programmng is slower due to complexity and use of Pascal. MSc has difficulty with prototype environment - dislikes changes.
D.	April'89	MSc accpts new job with Microsoft will leave May 15. Programmng continues. Recruitment begins.	Major push forces extra effort
		Demos provided for 4 spearate garment specialists - excellent feedback.	Encouragement for direction, some new ideas. Extensive use of interactive graphics surprises all who see system. Automatic batching and loading of work orders is seen as a major breakthrough in garment scheduling.
		Investor requests a market study.	Emphasis is shifting from the product to the business.
E.	May'89	Elect. Eng. with Mac experience is hired. EE begins orientation and programming familiarization. Msc completes working version.	Major slowdown in new develpment . Concern for time for EE to assume new role.
		EE begins testing- appears good. Another very good MSc Mac programmer offers services on hourly rate. Becomes a good resource.	Combination of MSc2 and EE appears to have promise.

F. June'89	Investor pushes for installation of Mac II at VP's offices on a monthly rental basis. VP agrees. Mac II installed at SSG. EE on site to assist in training and to learn how VP will use system.	Another deadline forces extra effort
	Re-organization of staff at NRC creates a potential conflict of interest between our project and a competitor. Considerable time spent in meetings. Decision to leave the CIIT at end of June.	External event forces departure. Fear that competitor has gained access to prototype jointly owned by NRC and SII.
	Market study identifys excellent potential assuming main requirements are in system. No direct competition seen. MRP systems seen as indirect competition.	Good encouragement - question now is "How to Market ?"
G. July-Aug'89	Office moved to investors location - working environment better. VP at SSG enters plans and booked orders for fall season. Too many bugs to allow proper use of system.	
H. Sept'89	J.Peterson takes demo to Bobbin Show and shows to major consultants. Response varies from exceptional to slight interest.	Deadline of show forces extra effort Initial version of a User manual is completed.
	Negotiations begin with a Los Angeles Macintosh Garment software co.	
	SSI develops a Lotus based Scheduling system for another season manufacturer.	New requirements identified: - material requirement representatio - departmental scheduling.

I. Oct-Dec'89	VP at SSG uses system for Sprin'90 season. System works ver well. Vp is able to identify and solve problems quickly. Time spent on scheduling decreases. Schedule report used in weekly management meeetings.	
	VP Finance at SSG reviews system. Will not pay rentals unless direct import from corporate database is operational.	New feature is consistant with Ph.D concepts so is added.
	Distribution contract completed with L.A. co.	Marketing is initiated.
J. Jan-Feb'90	Development continues on Import. Import is tested and is accepted.	Product development continues.
K. Mar-Apr'90	VP says results of first full season's use of system were very good. VP can not imagine scheduling without system. VP resigns - new scheduler(SCH) is assigned. EE trains and helps SCH begin new season (FALL'90).	This is first real evidence that the system works.
	SCH learn system in 2 weeks.	Another key milestone - a new user has learnt the system.
	VP leaves SSG - new VP was a client of SSI, and initially saw demo in April'89.	What changes will be made?
L. May'90	New VP(NVP) learns system and is very impressed.	
	J.Peterson presents paper at Hilton Head P/OM conference. JP surprised by response. CAASS is current with latest research, and ahead of many.	Other researchers reported some of Ph.D directions. Many Ph.D conclusions not yet seen. No similar garment system. Conference is 70% scheduling.
M. June-Aug'90	SSG continue to use system. NVP needs one graphic change.	Impatience with L.A. distributor.
	EE sent to L.A to train staff.	Concept is too new. Marketing problem.
	NVP reports that for the first time SSG had no late deliveries.	Proof that system works.
N. Sept'90	CAASS invited to show in Canadian Booth at Bobin Show.	
	Show response was positive.	Suggestion - have system write the cutting order. Good idea.
	Distributor has no sales.	Marketing problem.
O. Oct-Nov'90	Recession slows promised sales.	
	New Strategic Planning Session planned.	

Figure 7.6
Delivery System Representation



There were several important conclusions resulting from the Delivery System Development project. These are:

1. The addition of the MSc MAC programmer was very fortunate. His prior experience programming games on the MAC gave the project a new element of creativity. Interestingly, the VP was a very enthusiastic participant in all such discussions.
2. The ability to demonstrate the prototype, and the initial segments of the new system, especially in the light of the Ph.D research were significant elements in the decision of the external investor to join our efforts.
3. The time period from prototype termination to a working, usable system CAASS Version 1.0 illustrates the difficulty in converting research to application. The time periods are illustrated below:

	1987		1988		1989		1990	
Prototype	**	****	****	****				
CAASS V1.0					****	**		
CAASS V1.4						**	****	****

4. The further period from initial use i.e.Version 1.0, until the system proved its worth in a commercial environment, Version 1.4, illustrates the magnitude of the task of refining and enhancing Version 1.0 to a usable and useful system.
5. Among the many important ingredients that are necessary to convert research into application, persistent, patient, adequately financed believers are essential.
6. Although the permanence of the CAASS product and

company are far from established, one of the main reasons for its initial success is the quality of the research that is the enterprise's foundation. The pure research process is far more rigorous than the common commercial definition of requirements carried out prior to a system development project. Further, the fact that the guidelines and conclusions of the research were followed confirms this importance.

7. The design of the CAASS system introduced several refinements to the concepts and representations of the Prototype project(CAASS User's Manual 1990). The most significant of these were:

   1. Multiple user controlled mouse functions, organized into a "schedulers toolbox" that facilitates the scheduler's adjustment of the Work Orders in any schedule and facilitates the design and evaluation of options to improve schedules.(Figure 7.6)
   2. Representation of time, capacity and demand in a continuous x-axis with the lowest time unit equal to 5 minutes.
   3. Representation of capacity and demand as rectangular sections based on capacity specified to the day level.
   4. Several variations of the automatic load function, allowing for loading at the start, middle or end of the "Production Window".i.e. optional selection of the dispatching process,

8. New functions and options were added to allow the following:

1. Automatic Creation of Work Orders(WO), by batching individual product orders from all customer sales orders. This Batching process was based on the scheduler's rules and methods.
2. Sequencing of the Work Orders for automatic loading based on a ranking process using a multi-factor linear weighing process. The factors and weighing equation were intended to represent the expert's rules and processes.i.e.user defined sequencing options
3. Use of colours to represent capacity, demand-WOs, on-time WOs, late WOs, early WOs, and performance measures of percent of WOs on-time and late.
4. Three sets of user commands and functions to facilitate working with scheduled Wos(allocated), unscheduled Wos(unallocated) and capacity adjustments.
5. The ability to work with multiple production lines at once and load unscheduled Wos from one line into another line automatically.

8. One of the new conclusions that has been realized from the limited use to date of the CAASS system is that the tool itself has created a new type of expert, that being the expert automated system scheduler.

7.7. THE RESULTS

Using the Case Description Outline(CDO) prepared in Chapter 4, the corresponding detailed observations have been prepared. The detailed CDO for Case III is in Appendix B3.

The purpose of the case evaluation was defined to be the testing of the hypotheses. The specific research hypotheses to be tested were:

H5: The use of DSS technologies results in successful GMI scheduling systems.

H6: The use of Expert Systems Technologies results in successful GMI scheduling systems.

H7: The merging of DSS and ES technologies(DSS/ES) results in successful Garment Industry Scheduling Systems.

The Case III hypothesis testing is conducted as follows:

1. **Using the CDO; is the case an example of a DSS, ES or DSS/ES system ?**

Is the system an ES?

The Setting: The intent of the project was to solve a scheduling problem utilizing Expert Systems technology.

Design methodology: Case III methodology followed the generally accepted ES methodology.

Design Representation: As reported in Chapter 4, there are very few expert scheduling systems(ESS) in operation from which to define comparison criteria. Therefore, conclusive identification is not possible.

The comparison of the prototype and the delivery system with general characteristics and representations of Expert systems is illustrated in the CDO Appendix B3.

In conclusion, the system has several features that designate it as an ES, and differentiate it from a DSS. eg: representation of expert's heuristics for work order batching, sequencing orders, assigning orders to the production lines.

Is the system a DSS?
There are several components of the methodology and system that are characteristic of DSS systems. E.g: Prototyping, focus on decision maker and decision processes, provision of tools to support choice point of decision.
Thus the system may also be a DSS.

Does the system represent a merging of DSS and ES technologies?
Since the system contains both ES and DSS representations, and was developed utilizing both DSS and ES methodologies, the system does represent a merging of both DSS and ES technologies.

2. **If it is, then, did the case result in a successful GMI scheduling system ?**

Results:

The resulting system was a success for the Case III company. Specifically it was deemed to be a success in the following ways:

1. The Expert used CAASS V1.1 from Oct'89 until leaving the company in April 1990. During that time he trained a production supervisor to operate the system. Both used the system as the sole scheduling tool.

2. One of the Expert's criteria for success was that the schedule be an accurate representation for the real world. In two season reported upon Vose(1990) indicated that from the start of the season to the end of the season(4 months), the system representation was less than 4 days from the actual. This criteria appears to emphasize a credibility question. Is the system believable?
3. Upon the Expert's departure from SSG, his replacement, also a VP Manufacturing, learned the system from the production assistant and from the CAASS staff. He was enthusiastic, and has stated several times that if he did not have the system he would not be able to do the job. A testimonial letter is appended in Appendix D.
4. In a meeting I had with the new VP manufacturing in April 1991, I asked if the company had sufficient experience to quantify the value of the system. Upon reflection he presented me with a comparison between a Sportswear line that had not been scheduled on CAASS in Jan-March 1990, but had in Jan-March 1991. the comparison is illustrated in Figure 7.5 below.

Thus the benefits and usage of the system confirmed that the system was used and useful.

Figure 7.5

Evaluation of CAASS Benefits		
Season	Spring'90	Spring'91
Division	Sportswear	Sportswear
Production Line	Line 1	Line 1
Scheduling Method	Manual	CAASS
Units Produced	20,000	40,000
Scheduling Problems	Weekly emergencies	None
Profit/Unit (estimated)	$30.00	$30.00
Profit x Units	$60,000	$120,000
Value Gain	0	$60,000

3. **If it did, then, which specific technology characteristics contributed to the success, and how ?**

From the CDO in Appendix B3, it is clear that several characteristics from both the ES and the DSS technology were present in this Case. The positive cause-effect result can be attributed to all those elements present. From my reflective analysis, I believe the most significant positive factors were:

1. The sustained continuity of the K.E. Team(Expert, NRC-K.E., and myself) during the prototyping period, and subsequently, the Delivery Team(Expert, Investor, Analyst-1 and Analyst-2). (Although Analyst-1 was only with the project from January 1989 to May 1989, his design of the mouse driven graphical representations was extremely valuable.)
2. The Project setting and facilities in each phase of the project were not wanting in any way, and complemented the development activities. These facilities included the financial resources, staff resources the required hardware and software, and the project offices.
3. Given the above, the prototyping process, with the appropriate tools, and the components of each of the ES and DSS methodologies seemed to blend together to lead from one step to the next until a collection of semi-structured concepts emerged into the early version of the prototype. From the

first version of the prototype to the last, progress was very rapid.

4. **From #1, if the case was not an example of a DSS, ES or DSS/ES, then, why was it not, and did these differences contribute to success or failure?**

   Not applicable

In conclusion, the Hypotheses H7 is supported by the experience of Case III.

7.8. CONCLUSIONS FROM THE DEVELOPMENT OF CAASS

The following conclusions have been formulated:

1. The development of the CAASS system followed a lengthy and costly research and development cycle. Although the study had limitations, in total, it is the culmination of the detailed research from 1984 to 1991. Fox(1986) has studied expert scheduling systems since 1981 and has developed very few working systems. Clearly, Expert Scheduling research is costly and time consuming.
2. The CAASS system has many limitations and must be viewed only as a first version. It does, however, establish the validity of the merged DSS and ES concepts.
3. The merging of the DSS and ES concepts did not follow the prior experience of an ES managing DSS techniques within(Bonczek et al 1981), rather CAASS is a DSS with powerful ES tools within the DSS framework. These concepts are illustrated in Figure 7.6 as follows:

Figure 7.6
Merged DSS & ES architectures

Bonczek, Hopsallple & Whinston 1981

ES controls DSS	
DSS TOOL 1	DSS MODEL 1
DSS TOOL n	DSS MODEL n

CAASS(1990)

DSS with ESS TOOLS & MODELS	
DSS TOOLs	DSS MODELs
ESS TOOLs	ESS MODELs

4. From the viewpoint of the solution of the GMI scheduling problem, perhaps the most powerful concept developed was the conversion of what is basically a detailed, numeric problem into a graphical representation of the problem with a corresponding ease of understanding and solution.
5. In its simplest form the CAASS system is a Scheduling Workstation, analogous to a word processor, or other function dedicated machine/system. It establishes the link between powerful commands to facilitate the processes with the expertise needed to manage the problem.

In conclusion, the development of the prototype and Delivery versions of the CAASS system may point a new direction for the development of Scheduling Systems, whether they be called Expert systems, or not.

PART III: ANALYSIS

CHAPTER 8 - CASE COMPARISONS

8.1 METHODOLOGY

8.1.1 Overview

This chapter presents a comparison and aggregation of the findings of the three cases. The comparison was conducted as follows:

1. The Hypothesis testing exercise for the three cases is compared, summarized and appropriate conclusions formulated.
2. The CDO for the three cases is compared and conclusions formulated.
3. The conclusions are compared with those of the DSS, ES and ESS literature.

Collectively, the three cases are then analyzed to identify the specific knowledge that a scheduler appears to possess and the types of tasks that a scheduler performs.

The conclusions presented are organized to address the following perspectives :

1. Garment Manufacturing Industry(GMI) lessons.
2. DSS perspective, and the confirmation or otherwise of this technology applied to the GMI scheduling problem.
3. ES viewpoint, and the confirmation or otherwise of this technology applied to the GMI scheduling problem.
4. A research viewpoint, can a researcher play multiple roles, and how did I perform in this role?
5. From a personal view, my observations and conclusions are recounted.

8.1.2 Hypothesis testing:

The purpose of the case evaluations was defined to be the testing of the hypotheses.

The specific research hypotheses to be tested were:

H5: The use of DSS technologies results in successful GMI scheduling systems.

H6: The use of Expert Systems Technologies results in successful GMI scheduling systems.

H7: The merging of DSS and ES technologies(DSS/ES) results in successful Garment Industry Scheduling Systems.

The specific testing procedure and a summary of the testing of each case is presented below:

1. Using the CDO; is the case an example of a DSS, ES or DSS/ES system ?

   Case I: A DSS system.

   Case II: A system solution with some DSS characteristics

   Case III: A DSS/ES system.

2. **If it is, then, did the case result in a successful GMI scheduling system ?**

   Case I: The DSS was successful.

   Case II: The system solution was not successful

   Case III: The DSS/ES solution was successful.

3. **If it did, which of the DSS, ES or DSS/ES technology characteristics contributed to the success, and how ?**

   Case I: The main DSS factors appeared to be:

The clear focus on the strong, capable, motivated decision maker-scheduler, and the prototyping methodology and tools.

<u>Case II:</u> Was not successful.

<u>Case III:</u> The main DSS/ES factors appeared to be: The consistency of effort of the Prototyping and Delivery teams, in an excellent environment, focusing on the elicitation and representation of the expert scheduler's structures, thought processes, decisions and actions in preparing and managing schedules.

4. **From #1, if the case was not an example of a DSS, ES or DSS/ES, then, why was it not, and did these differences contribute to success or failure?**

<u>Case I:</u> Not applicable.

<u>Case II:</u> This system and its development project was initiated without a scheduler or clear scheduling function in existence. Therefore the solution developed did not focus on an existing scheduler. Although there were other factors that contributed to the failure these did also.

<u>Case III:</u> Not Applicable.

5. **From #2, if the case did not result in a successful system, then why did it not, and do these reasons support the accepted wisdom of the**

relevant technologies ?

Case I: Not applicable.

Case II: The Case did not result in a successful system, in part, due to the absence of the DSS characteristics related to the scheduler, as described in #4 above. In addition, the other factors that seemed to have contributed to the failure were the re-allocation of the new scheduler to other duties, his untimely departure and, the absence of a continuous senior management emphasis. The re-allocation and lack of management emphasis were a result of the demanding and dynamic nature of the GMI.

The "accepted wisdom" of the Information Technology(IT) field addresses the importance of senior management involvement(Lucas 1975). The importance of the GMI environment as an IT success factor has not been specifically studied before, to my knowledge. The importance of environmental factors, in general, has been studied by Ein-Dor(1978).

Case III: Not applicable.

8.1.3 Timing

The calendar below indicates the approximate timing of this and the other two cases.

	1983	1984	1985	1986	1987	1988	1989	1990
Case I	**	****	****	****	**			
Case II						**	**	
Case III					**	****	****	****

8.2 COMPARISON OF CASES I, II, AND III

8.2.1 Dependent and Independent Variables

The CDOs for the three cases are described in Appendices B1, B2, and B3. General conclusions can seldom be formulated from only 3 cases(Hillway 1964). However, I do agree with Hillway(1964) who believes that case study comparisons have value, if only because, some hidden cause-effect relationship may be suggested that could lead to a theory, hypotheses, and further study towards general principles.

The comparison of each detail characteristic was conducted from the three appendices. I have analyzed, the results of the comparison and selected the following summary and conclusions.

The CDO comparison was based on the research concept of identifying and comparing dependent and independent variables. These were:

The independent variables were:

1. The Company Environment(The Setting), prior to and during each project, as suggested by several authors.(Gibson and Nolan 1974, Huff and Munro 1985, King and Kraemer 1984, Ein-Dor and Segev 1978).
2. The Design Process, as defined by the project methodologies.(Alter 1980, Montazemi 1986),Bailey and Pearson 1983, Raymond 1985).
3. The Design Representation, as embodied in the resulting systems.(Alter 1980, Montazemi 1986, Bailey and Pearson 1983, Raymond 1985, Martin 1984).

The dependent variable studied in this research is:

1. The Performance of the resulting systems in the form of success indicators suggested by Montazemi(1986), Bennet(1983), Martin(1984), Lucas(1975), Clowes(1979), and Vose(1990).

For each of these variables, I determined that a specific subset of the CDO characteristics were representative of the meaning and intent of these variables. In addition each case identified either a new factor or a refinement of a factor that appeared to be more important, than in the other cases. These factors are presented and assessed for each case in Figure 8.1., and summarized by variable in Figure 8.2.

Figure 8.1
Comparison of CDO Case Summary

		Case I	Case II	Case III
	Success Factors:**			
A.	Environment			
	-Snr Mngt Support			
	-Time	2	1	3
	-Emphasis	4	2	3
	-Consistency	3	1	4
	Total	9	4	10
	-Resources			
	-Funding	3	1	4
	-Users	4	1	4
	-Developers	2	2	3
	Total	9	4	11
	-Project Duration	4	1	4
	-Devel. environment			
	-Facilities	3	2	4
	-Office			
	-equip.			
	-software			
	-Team quality	3	1	4
	-Scheduler			
	-Developers			
	Average score	28/9= 3.11	12/9= 1.33	33/9= 3.66
B.	Design Process			
	Adherence to:			
	-DSS method.	3	1	
	-ES method.			
	-DSS/ES method.			4
C.	Design Representation			
	-User Interface	2	2	4
	-User Focus	4	1	4
	-Sched.Model	2	3	2
	-Sys.Response	2	2	4
	Average Score	10/4= 2.5	8/4= 2	14/4= 3.5
Average Score	(A+B+C)/3=	8.61/3= 2.87	4.33/3= 1.44	11.16/3= 3.7
System Performance				
	-Importance	4	1	4
	-Efficiency	2	2	4
	-Value to Co.	3	1	4
	Average Score	9/3= 3.	4/3= 1.3	12/3= 4.0

** Qualitative measures:Poor(1), Good(2), V.Good(3), and Excellent(4)(Montazemi 1988)

Figure 8.2
Case Comparison Summary of Success Factors

	Case:-	I	II	III
	Success Factors:			
1.	The Company Environment	3.11	1.33	3.66
2.	The Design Process	3	1	4
3.	The Design Representation	2.5	2	3.5
	Average	2.87	1.44	3.7
	Success Measure: System Performance	3	1.3	4

8.2.2 Analysis of Comparison:

The selection of score values was based on a consideration of system evaluation questionnaires by Montazemi(1988), and Ein-Dor(1978). I evaluated the factors and characteristics selected in Figure 8.1 four times; using 5 levels, 4 levels, 3 levels and 2 levels for scoring the factors. I selected the 4 level scores because I found the 5 levels offered no apparent advantage while the other levels did not offer sufficient range to represent the degree of the comparison.

The equal weighing that I gave to each variable was also arbitrary. To do otherwise, would represent a conclusion that I could not make based on the three cases. I also readily admit that as with all user questionnaires, subjectivity is a problem, which in my situation is even more emphasized since I am both researcher and subject.

Nonetheless, I believe the process of comparison was valuable since it has facilitated a more concise presentation of the comparisons and the general conclusions that this study indicates.

In the discussions of conclusions I have used the term "Critical" to mean, that the absence of this factor appears to lead to failure.

Specifically, I believe, that successful scheduling systems require the following elements:

1. Adhering to the generally accepted methodologies of DSS or ES are very important.(Cases I,II,III)
2. The absence of a capable and prominent scheduler in a recognized scheduling function, appears to be critical.(Case II)
3. The quality of prototyping tools appears not to be critical provided the development team can sustain two to four month periods during which enhanced versions can be presented to the expert or DM not less than once per every one or two week period.(Case III).
4. Consistency of senior management involvement is critical, because senior management provides the direction, motivation and solution of problems that can retard or destroy development projects.(Cases I,II,III)
5. Minimum project duration of 24 months appears to be critical.(Cases I,II,III)
6. If the scheduling model and its DSS and ES system representations satisfy the scheduler's structures and decision processes, advanced mathematical or OR/MS solution methods are not as critical as a powerful and friendly user interface.

7. A capable, well motivated development team of 3 or 4, including the user, that can remain together for at least 24 months, appears very effective.

8.3 COMPARISON WITH THE LITERATURE

The results of the three cases were compared with the relevant DSS, ES and ESS literature, as summarized in the CDO outline and in Chapter 4. I have divide my conclusions of these comparisons into the three areas of DSS, ES and ESS.

8.3.1 Comparison of Cases with DSS Literature:

I found broad agreement with the DSS success factors related to DSS Methodology and Design representations. The exceptions to this agreement were as follows:

1. While integration with the MIS system is desirable, if the need is sufficiently great, and the DSS good enough, users will tolerate re-entry of data, and use of more that one system to perform the scheduling function.(Case I)
2. The complexity of the user interface, and the number of operators in a system, is not a difficulty for a scheduler, provided the system supports the scheduling process.
3. A project duration of 24 months appears to be required because of the development time(6-12 months) to represent the complexity of the scheduling task and the need to establish system credibility over two seasons(12 months).

8.3.2 Comparison of Cases with ES Literature:

Only Case III can be compared to the ES literature. I found less agreement with the ES success factors than for the DSS literature comparison.

1. The ES Methodology was very appropriate for the Case III project. However, neither the prototype nor the delivery system contained explicit knowledge representation schemes or knowledge bases, in the form of rules, and facts.
2. While the Prototype was written in Lisp, the early attempt to use rules with ART was seen as inappropriate for the nature of the problem structures.
3. The representation of the CAASS heuristics for management priorities for ranking orders, batching orders and automatically loading work orders were equally difficult to implement in Pascal and Lisp.
4. The focus on the Expert was correct, but rather then identifying a rule structure of the type "If..Then..." as is indicated in many expert systems(Hayes-Roth, 1983), the rule structure was replaced by a model of the expert's view of how he wished to generate a schedule.
5. The task of preparing <u>any</u> schedule, was a sufficient achievement with significant value for the system to be deemed a success.
6. The focus on the Expert became one of elicitation of his knowledge in the form of the structuring of the problem and the construction of new structures to facilitate schedule preparation and manipulation.
7. Many Expert Systems perform a task from start to completion(Hayes-Roth(1983), with an explanation

following. The schedulers in Cases I and III demanded the ability to manipulate and refine the schedule, as the schedule evolved from the initial state to the session-end state. The explanation of the intermediate steps was not required, since each iteration or option test was initiated and controlled by the user.

8.3.3 Comparison of Cases with ESS Literature:

Apart from the ISIS system developed by Fox(1986), and FAMS by Nassr et.al.(1985) the only other comparisons are with unproven postulations.

In Fox's(1986) methodology, his approach is based on explicit enumeration or a search of all solution options. When this search proved impossible because of the number of combinations, he introduced constraints which reduced the search space size by identifying many solution options as violating one or more constraints. He then found that, the solutions space was either:

1. the Null Set due to the constraints,
2. still too large to make solution practicable, or
3. small enough to solve.

He solved the Null Set by using heuristics for relaxing the constraints. State 2 was further reduced until state 3 was achieved.

In CAASS, the use of constraints is explicit in the available capacity, and the production windows. When the autoloading is completed and work orders are unscheduled, the scheduler then evaluates the situation and selects which constraints to relax. Further research is needed to determine if the constraint relaxation by the GMI schedulers can be represented by heuristics.

The FAMS system developed by Nassr et.al(1985), schedules a machine job shop. It has a mouse initiated user interface, and a scheduling model that considers machine routing through multiple machines. This system has a form of weighing system for ranking factors to assign priorities jobs. These jobs are then loaded in sequence by priority. CAASS, also follows the approach of using a mouse interface, but extends it further to include icon operators which perform functions on the schedule. In this and in other functions CAASS has a more powerful user interface.

The FAMS system has a similar concept for order ranking as CAASS, although oriented towards the machine shop environment.

8.4 SCHEDULER KNOWLEDGE AND TASKS

8.4.1 Importance of Schedulers' Knowledge

During the course of my involvement in these three cases I have worked with several people deeply involved in the scheduling function, as well as performing the scheduling function myself in Case I, and training schedulers in Cases II and III. Consequently, I become very aware of what a scheduler does, how he thinks, how he constructs and solves problems. As a result of these activities and my research, I now possess considerable knowledge of several schedulers' knowledge, in addition to my own.

I believe that the documentation of what I understand to be a scheduler's knowledge is an important contribution of this research. In future scheduling research, with the apparent importance of focusing on the scheduler in both DSS and ES methodologies, this focused description will be useful as a comparison, and perhaps as a starting point for other studies.

This description will also be useful to GMI management to facilitate their understanding of the role and requirements of the scheduling function.

8.4.2 Elicitation and Documentation of Scheduling Knowledge:

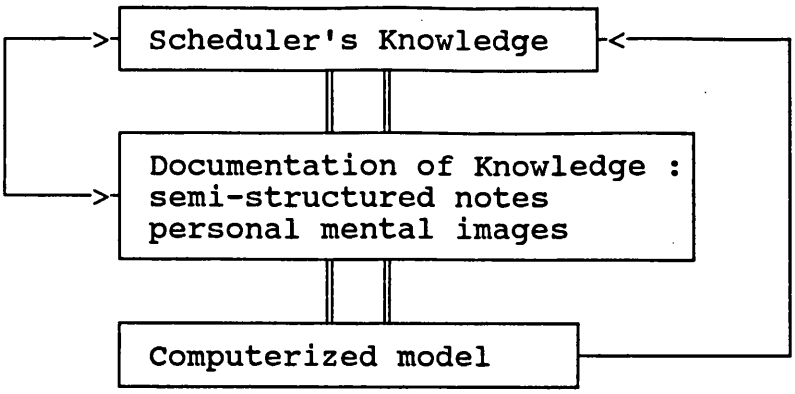
As I began to realise that I had acquired considerable knowledge of GMI scheduling I began to search for examples of how other researchers elicited and documented knowledge. In most DSS literature the emphasis is on the methodology of quickly representing the DM's structures in computerized models(Alter 1981), and not on the intermediate step of documenting the DM's knowledge. In the ES field, there is a clear recognition of the initial function of knowledge acquisition(Harmon & King 1984) as an interim step towards knowledge representation in a computerized system. There are several knowledge representation schemes that have been used in prior expert systems. The most popular of these are:

Rules;	If...Then..., and
Frames;	entities with attributes describing descriptors and relationships.(Feigenbaum, McCorduck and Nil 1988)

I observed that this process of arriving at a representation scheme, while facilitating the development of systems, bypassed the intermediate step(s) of documenting the actual knowledge in its "pure form", prior to coding in a structured system.

Since I used neither Rules or frames, in the formal sense, to develop the Case III system, I concluded the following:

1. The process of developing CAASS in Case III conveyed and transformed the scheduling knowledge through the following stages:



2. The cost and effort of achieving stage 2 should not have to be repeated each time another researcher or developer wishes to develop another scheduling system,
3. Future researchers and developers should be able to determine their choice of representation for step 3, without the encumbrance of having to wade through the mass of detailed code and documentation,
4. The need exists for formal yet flexible methods for documenting knowledge at the step 2 stage.

I refocused my literature search to the examination of knowledge description schemes that appeared to offer the potential for the documentation of a scheduler's knowledge. The search identified two knowledge documentation schemes that appeared to be appropriate. However, neither one was adequate to describe the scheduler's knowledge alone.

The two methods used are described by their authors as knowledge categorization; identifying knowledge categories(Vitalari 1985), and scenario analysis, identifying scenarios of sequential structured tasks(Schvaneveltt 1985). I approached the task of testing the appropriateness of each method by actually, documenting my understanding of scheduler knowledge using each method. While I concluded that neither method was adequate by itself, together they did accomplish the following:

1. the enumeration of the many types of specific information that a scheduler requires and possesses, suggesting the requirement for data/information linkages in an appropriate future system,
2. the initial formation of a theory of the differences between novice knowledge and expert knowledge, which may lead to a more expedient method of advancing a novice scheduler to an expert level,
3. the identification of specific scenarios that are common requirements of the schedulers studied in this research,
4. the identification of these scenarios suggests the nature and construction of advanced "scenario tools" composed of multiple information representations and complex operators linked into a close scheduler-machine interface to facilitate the rapid execution of a given scenario.

The exercise of applying both methodologies was valuable in the identification of underlying relationships that had not been studied in detail in Case III. These relationships, I believe are important because they define the requirements of scheduling systems from the perspectives of "basic scheduling knowledge" and "scheduling scenarios".

I have also concluded that my initial realization of the gap between knowledge acquisition and representation was correct and that more work is required in the development of formal methods for the documentation of pure scheduling knowledge.

8.5 SCHEDULING KNOWLEDGE CATEGORIES

8.5.1 Background

This section describes my attempt to use protocol analysis techniques(Vitalari 1985) to record GMI scheduling knowledge as knowledge categories(KCs). This exercise was undertaken as an exploratory and preliminary test to determine if the underlying concepts do, in fact facilitate the capture and documentation of scheduling knowledge. The prescribed methodology requires that the subjects be personnel who regularly perform the job function being studied, and the researchers be independent observers. In my use of the concepts I have been both subject and researcher, a limitation that compromises the methodology. However, my goal in attempting to use this technique is only to determine if the notion of scheduling knowledge categories(KCs) can assist me in the recording of scheduling knowledge. I claim no attempt at rigorous technique or general conclusions.

Since this technique is within the broad field of Expert Systems, this test is also another test of two of the original hypotheses, namely;

H6: The use of Expert Systems Technologies results in the better GMI scheduling systems.

H7: The merging of DSS and ES technologies results in better(useful and usable) Garment Industry Scheduling Systems.

The hypothesis testing becomes the question:
Does the use of the concept of knowledge categories(KCs) result in better GMI scheduling systems?

The answer will not be conclusive for some time, since the result of this use of knowledge categories will not be seen until, and if, the recorded KCs are used to produce future better systems. At this time, based on my use of the KC concept I believe the concept has been useful in capturing, for future use, a collection of KCs that I believe to be representative of those possessed by the scheduling personnel that I have worked with in the Cases presented in this thesis. While I believe the list of KCs to be representative, I have no way of assessing its completeness.

8.5.2 Knowledge Classification

In 1985 a study was conducted by Vitalari(1985) to identify the types of knowledge utilized by systems analysts in the initial stages of the definition of requirements for a common commercial application system. The specific task was to determine the information requirements and functional specifications of an accounts receivable system for a low margin, high volume retailer. The task was viewed as only the starting point of the entire problem solving process.

The method to identify each analyst's "knowledge" was as follows:

> "Protocol analysis is a data collection technique that focuses upon the cognitive process and content of a problem solving task. The cognitive process is observed by requiring the subject to think aloud while performing a task. ... A protocol coding scheme consists of series of categories about the behaviour to be studied. In this study the coding scheme consists of detailed categories of knowledge with definitions. The coding scheme is used by one or more coders to extract relevant information from the protocols. The results of the coding process are then statistically compared for inter coder agreement. The coded information becomes data for the analysis." (P226) Vitalari(1985)

The resulting KC are classified into four types of knowledge, namely;

1. Applications Knowledge, that relates specifically to the general scheduling area.
2. Functional Knowledge, of the specific management disciplines of finance, accounting, production, etc.
3 Organizational Specific Knowledge, specific to a scheduler's organization.
4. Knowledge of Methods and Techniques, related to specific analysis techniques, methodology and approaches used to schedule.

Knowledge within these four types can also be classified as:

1. Core Knowledge, which is necessary for any individual in that domain to perform at a satisfactory level.
2. High Rated Knowledge, possessed by high performers.

The distinction between #2 and #1 appears to be that the high rated group will place more emphasis on certain KCs. In discussing these terms the authors identify the concept of decision making as a type of activity that can be viewed as requiring expertise. This is important to the study of production scheduling expertise.

8.4.3 Scheduling Knowledge Categories

In Vitalari's(1985) representation knowledge is grouped into the categories of:

1. Functional - These being the organizational functions and interrelationships. From a scheduling viewpoint these would be the different organizational departments and divisions such as sales, marketing, finance, accounting, production, design, distribution, customer service and scheduling.
2. Application specific - In this respect the knowledge for scheduling would be seen as that which is used to perform and manage the scheduling functions.
3. Organizational specific - In the scheduling study this knowledge would relate to the specific personalities, politics, policies, history, plans and practices of the specific company within which the scheduler performed his functions.
4. Methods and techniques - In this respect the scheduling methods and techniques which were embodied in the three case systems well as the other activity patterns and tasks performed by the scheduling team would be included in this grouping of knowledge.

In an attempt to identify the relevance of the above knowledge framework, the protocol analysis and the "knowledge category" identification I undertook to identify a variety of "knowledge categories" for the scheduling environment. Unlike Vitalari's(1985) study, formal protocol analysis was not conducted. Rather documentation acquired over six years work with the scheduling personnel and from my own knowledge and experience was used to identify the knowledge categories. These knowledge categories, grouped according to Vitalari's(1985) classifications are recorded in Figure 8.3. Conclusions in carrying out this analysis and from analysis of the knowledge categories are discussed in a following section.

Figure 8.3
SCHEDULING KNOWLEDGE CATEGORIES

	Knowledge Category	Functional	Application	Org. Specific	Method & Tools
1.	Sales Forecasting Concepts	X	X		
2.	Sales Estimates/Style		X	X	
3.	Sales Trends/Season			X	
4.	Seasonal Trends from year to year		X	X	
5.	Sales Manager's Forecasts and Post Accuracy			X	
6.	Financial Plans	X	X	X	
7.	Seasonal Financial Plan			X	
8.	Unforecasted Sales			X	
9.	Rush Orders			X	
10.	Repeat Orders			X	
11.	Make-for-Stock Orders		X	X	
12.	Customer Orders			X	
13.	"Make-to-Order" Orders		X		
14.	Line Estimates (Collection)			X	
15.	Work Orders Issued		X	X	
16.	Word Orders to be Issued		X	X	
17.	Style Classification (Type)		X	X	
18.	Average Minutes/Style Type		X	X	
19.	Plant Capacity in Minutes/ Day, Week		X	X	
20.	Plant Capability by Style Type (or Style Types Made in a Plant)		X	X	
21.	Long Term Plans	X	X	X	
22.	Short Term Plans	X	X	X	
23.	New Plant Plans			X	
24.	Plant Closing Plans			X	
25.	Contractors Available		X		
26.	New Contractors Available		X		
27.	Contractor Closings		X		
28.	Contractor Capacity		X		
29.	Contractor Capabilities/ Characteristics		X		
30.	Problems With Contractors			X	
31.	Seasonal Cycle for New Products	X	X	X	
32.	Collection Cycle for New Products		X	X	
33.	Collection Characteristics			X	
34.	Seasonal Characteristics			X	
35.	Problems with Plants			X	
36.	Labour Characteristics by Plant			X	

Figure 8.3 continued

Knowledge Category	Functional	Application	Org. Specific	Method & Tools
37. Labour Training Requirements		X		
38. Labour Force Characteristics	X			
39. Manufacturing Flow	X	X	X	
40. Manufacturing Processes		X	X	
41. Manufacturing Process Characteristics			X	
42. Manufacturing Process Problems			X	
43. Product Design & Engineering Processes	X	X	X	
44. Competitor Companies by Region	X	X	X	
45. New Competitors		X	X	
46. Competitor Closings		X	X	
47. Scheduling Systems Characteristics		X	X	X
48. Scheduling Reports		X	X	X
49. Scheduling Use of Computers		X	X	X
50. Development of Scheduling Systems		X	X	X
51. Scheduling Data Available (by Computer)			X	X
52. Scheduling Graphs & Charts		X	X	X
53. Scheduling System Problems			X	X
54. Scheduling System Improvements Needed			X	X
55. Scheduling Concepts		X		
56. Scheduling Systems Functions/ Operations			X	X
57. Scheduling Information Types		X		
58. Scheduling Information Sources			X	X
59. Non-Scheduling Systems	X	X		X
60. General Manufacturing Co. Organization	X			
61. Garment Manufacturing Co. Organization		X		
62. Specific Co. Organization			X	
63. Staff Positions and Responsibilities			X	
64. Staff Capabilities and Characteristics			X	
65. Staff Most Closely Related to Scheduling			X	
66. Work-in-Process Concepts		X	X	
67. Production Cycle & Turnaround		X	X	
68. Work-in-Process Minimum, Maximum Targets		X	X	
69. Specific Process Bottlenecks			X	
70. Common Manufacturing Problems by Style Type		X	X	

Figure 8.3 continued

	Knowledge Category	Functional	Application	Org. Specific	Method & Tools
71.	Common Manufacturing Problems by Fabric Type		X	X	
72.	Fabric Characteristics		X		
73.	Fabric Vendor Characteristics	X	X		
74.	Fabric Shippers	X	X		
75.	Fabric Shipping Options by Vendor		X	X	
76.	Fabric Shipping Lead Times by Vendor		X	X	
77.	Fabric Requirements Processing				X
78.	Fabric Purchasing Process and Cycle	X	X	X	X
79.	Non-Fabric Vendors, Shippers, etc.	X	X	X	
80.	Non-Fabric Vendors, Purchasing, etc.		X	X	X
81.	Non-Fabric Requirements Processing				X
82.	Fabric Purchasing Problems		X	X	
83.	Non-Fabric Material Purchasing Problems		X	X	
84.	Fabric Quality Problems		X	X	
85.	Finished Garment Quality Problems		X	X	
86.	Quality Problems by Manufacturing Process and Plant			X	
87.	Fabric Cutting Processes (including bundling, etc.)	X	X	X	
88.	Marker Making Process	X	X	X	
89.	Piece Goods (Cut Pieces) Shipping to Plants		X	X	
90.	Sewing and Manufacturing Operations	X	X	X	
91.	Operations List by Style		X	X	
92.	Bill of Material by Style		X	X	
93.	Piecework Ticket System	X	X	X	X
94.	Piecework Payroll System	X	X	X	X
95.	Interrelationship of Activities and Functions	X	X	X	
96.	General Product Cycle & Timing	X	X	X	
97.	Specific "Collection" Cycle and Scheduled Dates		X	X	X
98.	Collection Cycle and Schedule Problems		X	X	X
99.	Scheduling Dept Activity Cycle		X	X	X
100.	Purchasing Activity Cycle		X	X	
101.	Product Design Activity Cycle		X	X	
102.	Engineering Activity Cycle		X	X	

Figure 8.3 continued

	Knowledge Category	Functional	Application	Org. Specific	Method & Tools
103.	Production Activity Cycle		X	X	
104.	Distribution/Fin. Inventory Activity Cycle		X	X	
105.	Customer Shipping Activity Cycle		X	X	
106.	Collection Delivery Dates		X	X	
107.	Problems with Scheduling Activity Cycle		X	X	
108.	Problems with Purchasing Activity Cycle		X	X	
109.	Problems with Prod Design Activity Cycle		X	X	
110.	Problems with Engineering Activity Cycle		X	X	
111.	Problems with Production Activity Cycle		X	X	
112.	Problems with Distribution/ Fin. Inventory Activity Cycle		X	X	
113.	Problems with Customer Shipping Activity Cycle		X	X	
114.	Problems with Collection Delivery Dates		X	X	
115 - 122	Impact of Problems in Areas 107 - 114		X	X	
123 - 130	Remedial Action Options for Problems 107 - 114		X	X	
131 - 138	Problem Predictors (Warning Indicators) for Problems 107 - 114		X	X	
139 - 146	Problem Prediction, Preventative Response Actions for 131 - 138		X	X	
147.	General Company Policies and Practices		X	X	
148.	Interrelationships Between All Types of Problems		X	X	
149.	Corporate Goals and Objectives, Mission	X	X	X	
150.	Senior Management Preferences and Priorities		X	X	
151.	Senior Management Meeting Structure and Schedule		X	X	
152.	Scheduling Committee Meeting Schedule		X	X	
153.	Scheduling Committee Agenda and Practices		X	X	
154.	Current Long Term Schedule Contests			X	X

Figure 8.3 continued

	Knowledge Category	Functional	Application	Org. Specific	Method & Tools
155.	Current Short Term Schedule Contests			X	X
156.	Historical Crisis Situations		X	X	X
157.	Historical Critical Events		X	X	X
158.	Significant Historical Opportunity Situations		X	X	

8.5.4 Analysis of Scheduling Knowledge Categories:

From my analysis of the scheduling knowledge categories illustrated in Figure 8.3, I observed the following:

1. The number of knowledge categories (KC) classified as Functional (specific management disciplines) is less than 20% of the total knowledge categories identified. In defining knowledge categories and classifying them, I found that a KC classified as functional represented more general concepts and relationships than did non-functional KCs. In this respect, for example, "sales forecasting concepts" (KC #1) represented various ideas and concepts of sales forecasting.
2. The Application knowledge categories (relating to the specific functions performed within the domain) represented approximately 50% of all KCs. In defining a KC in the classification of APPLICATION, I found that such classifications were made when the answer to the question "Would this knowledge category be found by schedulers in various organizations?" was "yes".
3. The number of KCs classified for ORGANIZATIONAL SPECIFIC (specific KCs found in the organization studied) was in excess of 90% of all KCs. In this respect the reality that the scheduling function is an organizational dependant activity is clear.
4. The number of KCs classified as Methods, Techniques or Approaches was less than 20% of all KCs. The initial interpretation of this phenomenon was that these knowledge categories are likely represented by specific systems, procedures or definite policies within the organization. In a few cases where common industry

wide systems applied, example KC #93, this classification was used because of its industry wide acceptance and understanding.

5. Several KCs could easily be classified in two or more of the classifications. In this respect a given knowledge category such as KC #96, general product cycle and timing, could be related clearly to the functional classification in that it is an industry wide or general concept descriptive. Clearly this descriptive also is related to the specific application of scheduling. In addition each specific organization has its own product cycle and timing.
6. KCs that were classified as both organizational specific and methods, techniques and approaches, example KC #56 "scheduling system functions/operations" were clearly specific to the organization as well as indications of systems or procedures.
7. KCs which were classified as "application or domain, organizational specific, and methods, techniques and approaches", were seen as the knowledge categories that were relevant to the overall scheduling function and as well specific in its implementation for a given organization.
8. Certain KCs such as KC #39 "manufacturing flow" and KC #40 "manufacturing processes" could be seen as viewed from the scheduling function as being represented in the knowledge classifications of functional, application, and organizational specific. From a scheduling viewpoint these processes do not represent specific methodologies, techniques or approaches.

9. Throughout the list of KCs, there are several references to knowledge related to different "problems". This emphasis on problems may be explained by the cases studied and their situation in the periods studied. For example, in Case I, my deep involvement occurred at the time when the scheduling problems were unsolved. In contrast, in the period May 1990 to July 1991, the Case III company has had very few problems, due in part to the ability to identify and resolve potential scheduling problems before they occur.

10. Problems which are most relevant to the scheduling activity are those identified and related as KC #96 to KC #146. I found it relatively easy to identify the functional or conceptual knowledge categories which are most critical to the scheduling function, i.e. KC #99 to KC #106. Having identified these knowledge categories it was then easy for me to identify problems with these same knowledge categories, i.e. KC #107 to KC #114. It was also easy to enumerate the next logical grouping of categories; those that describe the impact of the problems, i.e. KC #115 to KC #122. It was then a sequential thought process to identify the remedial actions/options for the problems described by the previous impacts, i.e. KC #123 to KC #130. In considering this relationship between knowledge categories, i.e. problems, impacts and remedial actions, I then had the realization that there exists another set of knowledge categories which could be described as "problem predictors or warning indicators" for a given problem. These are identified as KCs #131

to #138. The realization then followed that with the identification of a problem predictor or warning indicator the scheduler then often has the opportunity to respond with a preventative action in an attempt to ward off the problem even though it is potentially imminent because of the problem predictor identification. These "problem prediction preventative response actions" are identified as KC #139 to KC #146. In summary the KCs related to problems are:

1. Problem predictors or warning indicators,
2. Problem prediction preventative response actions,
3. Problems being the occurrence of a situation at variance with that desired,
4. Problem impacts or effects of problems,
5. Remedial actions/options for problems once they have occurred.

8.5.4 Conclusions from Knowledge Category Analysis

From my analysis of the recording of the KCs and from my subsequent examination of the KC themselves, I formulated the following conclusions:

1. The successful schedulers that I worked with in Cases I and III new considerable about their organization, i.e. Organizational KCs.
2. Knowledge categories which represent the prediction, response, identification, impact and resolution of problems are fundamental in the performance of the scheduling function at an expert level. Clearly an expert scheduler will have more success at avoiding,

and when they are unavoidable, responding to problems than a novice.

3. A strong knowledge of the interrelationship between all types of problems (KC #148) also would be found and has been identified as a fundamental knowledge category possessed by an expert.
4. The successful schedulers possessed an excellent working knowledge of the tools of their discipline, i.e. "methods, techniques and approaches". In addition, knowledge categories related to the improvement of these methods, techniques and approaches were also highlighted by these schedulers.
5. The "good" or expert schedulers that I am aware of also possess the attribute of having worked in more than one organization. In this respect those knowledge categories that are classified as application or domain specific are highlighted. It would appear that this classification of knowledge, i.e. "application or domain" is not as important as the knowledge categories related to problems and methods and techniques which are more organizational specific. At the same time, however, it is reasonable to expect that a scheduler who has had experience in several related organizations would be able to perform at a high level in any organization because of his awareness of the key knowledge categories, i.e. key processes and types of problems that are fundamental to the scheduling task.
6. Many of the knowledge categories have a very close relationship to information and/or data which would normally be assumed to be in the organization's

corporate information systems. For example, sales estimates by style, financial plans, customer orders, work orders issued, bills of material, average minutes per style type, etc., are fundamental values in the corporate information system describing the organizational systems. The data base structure of the traditional MIS manufacturing system defines the relationships between the products, the bills of material, labour, etc. Each one of these files, i.e. bills of material contain specific factual data on the relationship described by the file.

7. In addition to the KCs of #6 above for the main data groupings such as vendors, styles, customers, plants, etc, their exists knowledge possessed by the scheduler about these entities, that was not stored in the corporate information systems studied. The schedulers studied also possessed knowledge <u>about the data</u> that they used to assess a given situation. For example, the reliability of a fabric mill in achieving quoted delivery dates is knowledge that has been acquired over time and from others. While some of the raw data to make such an assessment may be available in the corporate system, the scheduler possess the knowledge of the data analyzed into information, as well as his own assessment based on information and assessments from other sources. He also has a belief of how the mill will likely perform in the future based on recent tends or external information such as an expected shortage of shipping capacity.

8. The analysis of points #6 and #7 above leads to the

conclusion that there exists not only a manufacturing database that logically links the different types of data, but there also exists a collection of knowledge <u>about the database</u>. This parallel knowledge base would appear to have similar linkages and relationships to those of the database. The "shadow" or "parallel" knowledge base structure would contain the scheduler's commentary or interpretation of the actual data base. For example the vendor data base segment for a given set of raw materials contains the vendor's name, address, year to date purchases, outstanding amount owed, last receipt date, last purchase order date, and several related facts. The "shadow" or "parallel" knowledge base would contain the scheduler's experience, evaluations, judgments, preferences, and a cross reference to historical problems and incidence related to each vendor. as illustrated in Figure 8.4.

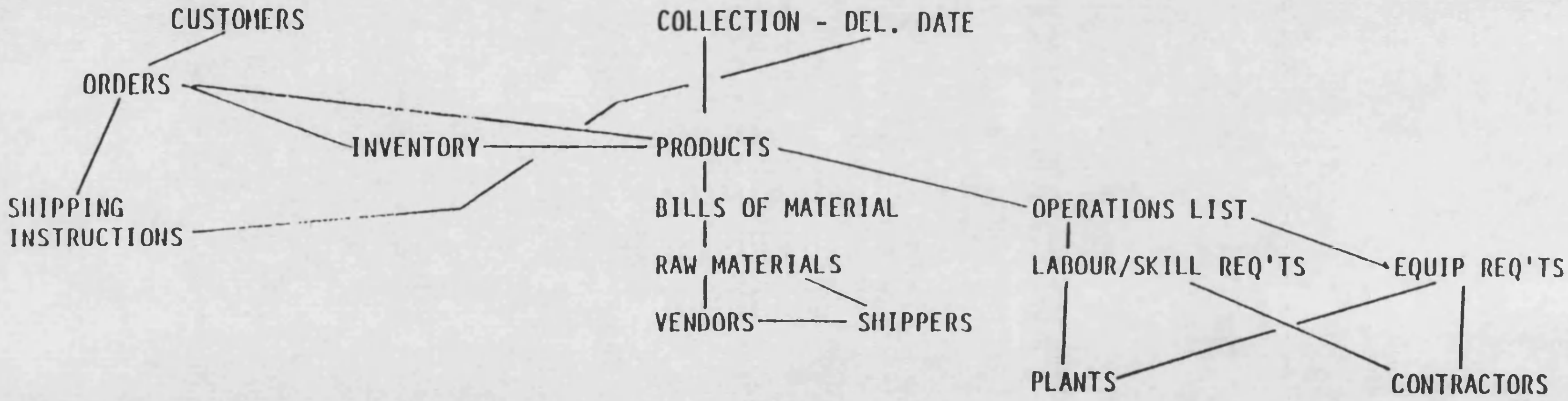


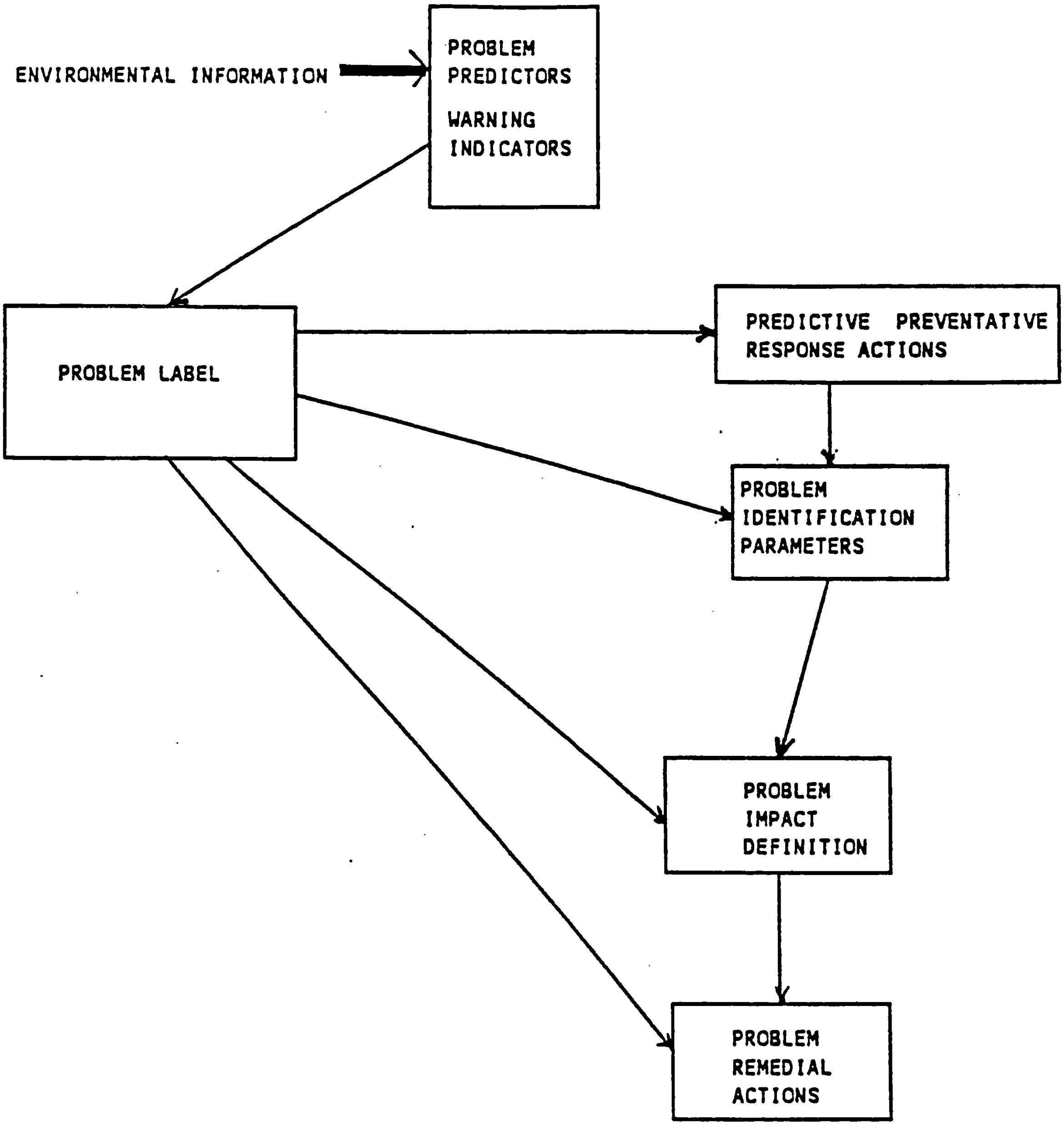
Figure 8.4
Manufacturing Database/Knowledgebase Structure

9. Examining further the concept of a scheduling knowledgebase with linkages, analysis of the KCs leads to the identification of several additional groups or collections of knowledge that would also be linked or cross referenced.

10. The importance of the scheduler's knowledge related to the problems was discussed previously. Applying the concept of linkages between groups of KCs to the problem KCs leads to a knowledge base between the problem predictors, or warning indicators, predicative preventative response actions, problem identification, problem impact, and remedial actions. The corresponding knowledge base would identify each of these relationships and descriptive. A suggested structure for such a segment of the knowledge base is illustrated in Figure 8.5.

Figure 8.5

Problem Knowledge Base



11. This representation of a problem knowledge base(Figure 8.5) illustrates the concept that a problem predictor or warning indicator would be described by either the occurrence of a specific event or information relating to the planned or expected occurrence of an event. This event would then be related to the specific description of the problem with a corresponding description which is further cross referenced to the impacts or effects of the problem with each such impact or effect being cross referenced to an appropriate remedial action or series of actions. In addition each problem predictor or warning indicator would be linked to the problem predictor preventative response action or series of actions which could be taken to prevent the problem. In Appendix F, This schema has ben represented as a set of PROLOG statements.

12. This emphasis on problems is further illustrated with the knowledge category KC #148 which describes the interrelationship between all different types of problems. This concept of interrelationship of problems can be represented as a network of problems relating to a reduced collection of "ultimate problems", such as "late Customer Delivery" for a given style or customer order. The representation of the relationships of problems is very difficult in a two dimensional medium. Conceptually, the inter-relationships could be presented as "influence diagrams" or, more simply as a hierarchy of sets of problems that are seen to be interrelated in either a sequential manner or in some fashion through

directed arrows indicating cause and effect. The example illustrated in Figure 8.6 shows the impact or interrelationship of a series of problems to the delivery problem. In this problem working from the ultimate "delivery lateness" backwards, contributing problems can be identified as "production being late into distribution", or, "distribution overload" thus not being able to fill and ship the customer orders on time, or, "trucking", or, other "conveyance strikes "and" weather conditions" as being among the potential problems which could result in the ultimate problem of "late delivery". Each one of these intermediate problems can also be identified in the same framework having a series of interrelated problems which would cause that individual intermediate problem to occur.

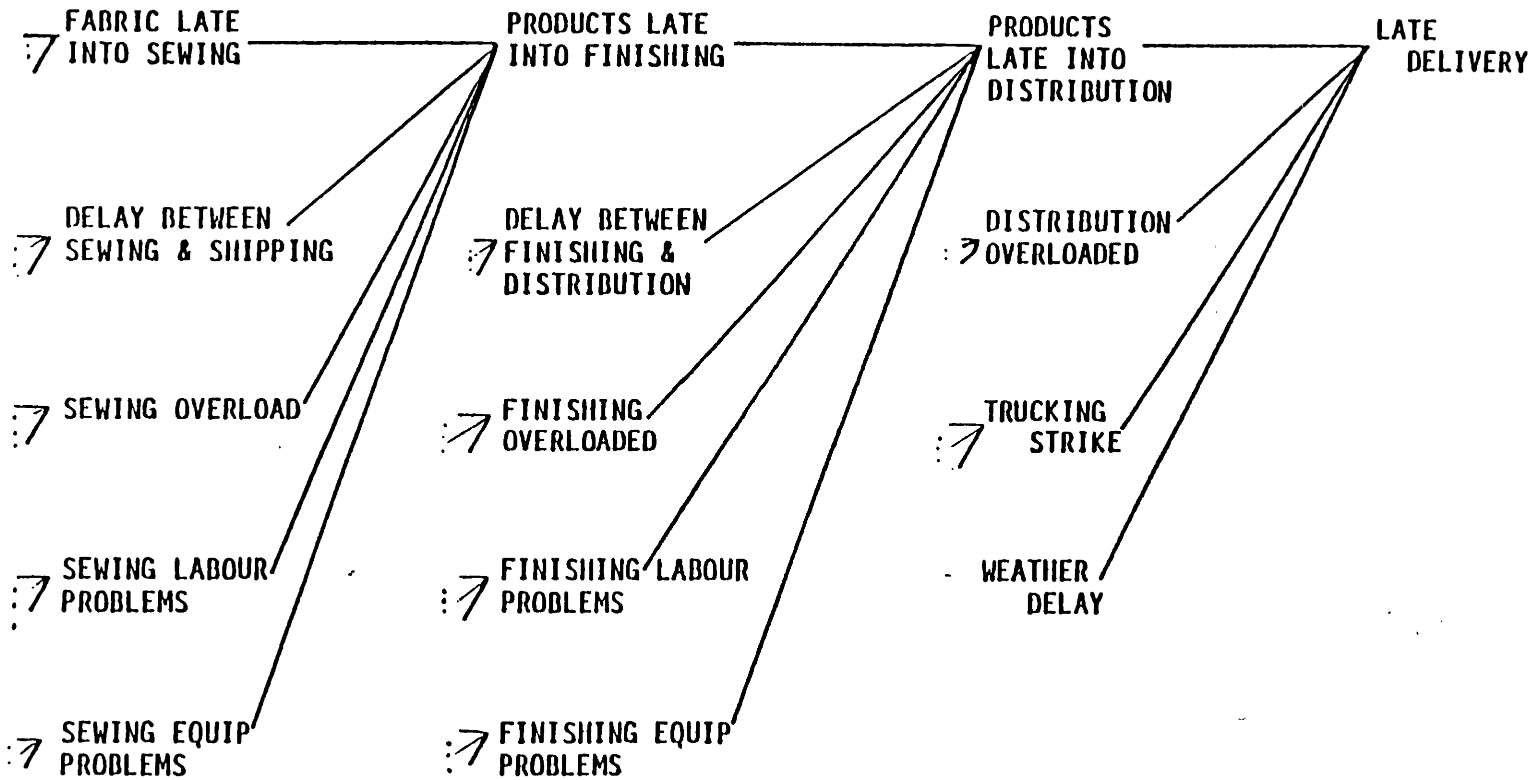


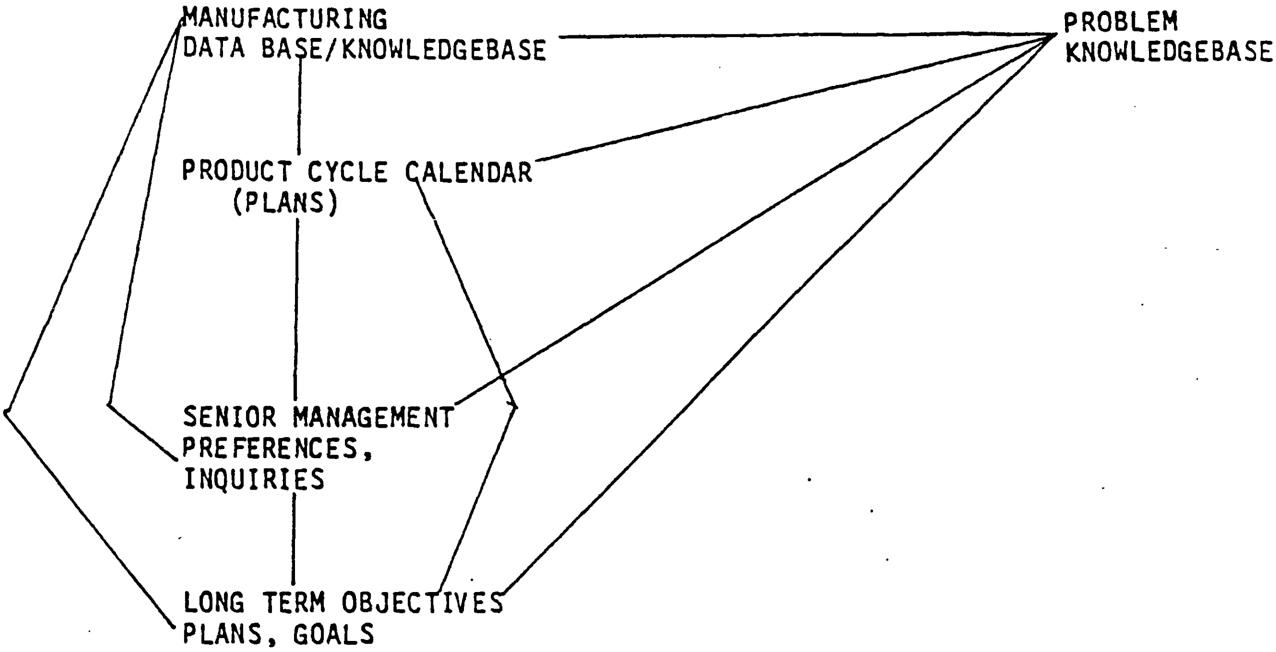
Figure 8.6
Problem Inter-Relationships

13. Another very important set of knowledge categories represents "senior management preferences, typical enquiries, and the corporate goals, objectives and mission". Individual knowledge entries in these knowledge categories would link to the appropriate entities in the other knowledge bases.

14. Relating the prior concepts of "data base/knowledge base parallel", problem knowledge base representation and problem interrelationship results in the identification of the need for a cross referencing or linkage capability between the entities of each knowledge base segment in order to allow for appropriate linkages to complete the representation. This concept is illustrated in Figure 8.7 entitled Knowledge Base Linkages.

Figure 8.7

Knowledge Base Linkages



8.6 SCHEDULING SCENARIOS

8.6.1 Scenarios

The concept of a scenario analysis has been used by Schvaneveldt(1985) to attempt to describe another viewpoint of knowledge. A Scenario is a term used to describe an initial state of an environment or domain and the unfolding of that environment as it evolves towards subsequent states(Schvaneveldt 1985). Scenarios can be used to describe virtually any environment or domain. In the scheduling domain studied in this research the analysis of scenarios has been useful because many scenarios are repeated in the scheduling cycles,i.e. daily, weekly, monthly, seasonally or yearly. The scheduling function is performed in a dynamic environment where situations change rapidly and each situation can be viewed as a scenario.

From my analysis, experience and understanding of the scheduling function, a variety of scenarios were identified and are illustrated in Figure 8.8. These scenarios reflect actual situations which occurred in at least one of the Canadian, English or Finnish companies studied.

FIGURE 8.8
SCHEDULING SCENARIOS

1. Comparison of Financial Plans for a given "time period" with the sum of the units to be produced and the units scheduled in the same "time period", and the corresponding monetary values,

2. The above analysis for a given "line or collection" instead of the "time period".

3. Categorization of a style by manufacturing capability requirements.

4. Analysis of the manufacturing plant options for the production of a given style or style type.

5. Assignment of a style or style type to a specific plant.

6. Setting up a style or collection of styles on the Long Term Plan using the computer system.

7. Revising style sales estimates on the Long Term Plan or the Short Term Plan.

8. Moving a style or collection from one plant (or contractor) to another, or from one time period to another in either the Long Term or Short Term Plan.

9. Deletion of a style or collection due to cancellation.

10. Review of Delivery Performance in the past six months for management.

11. Forecast of Delivery Performance for the next six months for management.

12. Review of capacity in units per week over the past six months and expected capacity for next six months.

13. Analysis, in units/week and cumulative units/week of capacity shortfall or surplus over the next six months.

14. Analysis of the total requirements of a group of raw materials over the next three months based on the units scheduled in the "Short Term Plan".

15. Analysis of the impact of a raw material arriving four weeks later than planned.

16. What are the scheduled deliveries to customer #1 over the next six months?

17a. When is the earliest we can ship "Rush Order #99" to Customer #1 without causing late deliveries to other customers?

FIGURE 8.8 continued

17b. If we ship Rush Order #99 by Jan. 1, 1988 which customers, products and orders will be late?
- What are our options?
- What other problems will this cause?
- What is the preferred option to achieve this delivery and minimize the delay to other customers?

18. Analysis of Impact of Customer #2 just doubling his order: - How much can we deliver on time?
- What changes do we need to make to deliver it all on time?

19a. Analysis of impact of possible shortages of materials coming from Japan.
- What are the materials, styles, orders and customers effected?
- How much of each material do we need?

19b. If we can buy all our next year's requirements immediately and take delivery in six weeks we will want to use this material as fast as we can
- reschedule all production, to use this material as soon as possible without creating delivery problems and produce a material requirements schedule showing quantities required by week.

20. A competitor is laying off experienced staff - should we hire any of these workers?

21. Analysis of next year's capacity and labour requirement fluctuations greater than 10% of last year averages.

22. Analysis of plants to determine which facilities to use for new products A, B and C.

23. Analysis of plant, labour and operations consolidation if forecast sales are reduced by 50%.

24. Analysis of implications of a labour strike in Plant 6.

25. A new line of sewing equipment is available at an introductory discount should we buy any machines?

26. What is the number of orders and units scheduled to be shipped in the eight weeks of July and August - several shipping staff want to take vacation.

8.6.2 Analysis of Scheduling Scenarios

Several of the scenarios identified in Figure 8.8 were reported in a prior publication entitled "Can Expert Systems Help Production Scheduling" (Peterson 1987).

Reviewing the scenarios described illustrates a number of conclusions, namely:

1. Each of these scenarios refers to a series of processes, steps or activities that produces some information for the purpose of management of the scheduling function and of the company.
2. The scheduler in carrying out the activities in any given scenario can be seen to follow a process similar to the following steps:
    1. Analyze required information and operations.
    2. Identify the sources of information and formulate a solution approach (this may involve several information sources and several steps).
    3. Execute the operations involved in obtaining the information required and processing or manipulating information accordingly.
    3. Accumulate the results and present them in an appropriate manner.
3. There are a definable number of functions, i.e. comparison, select, input, delete, summation, difference, calculation, etc., which describe the majority of operations.
4. The qualification of the data to be analyzed refers primarily to: specific periods of time, styles within a collection, styles within a plant, (or scheduled to be produced in a plant), styles manufactured for

specific raw materials, and styles represented in selected customer orders.

5. The arguments or operands of these functions or operators refer to a finite set of information entities; namely, financial plans, units scheduled for a style for a week, style operations and required equipment list, style estimates, shipping date of an order, collection delivery date, units produced in the past, styles pertaining to particular order, orders pertaining to a particular customer, etc.
6. The structure describing the above relationship between operations, information and operands is illustrated in Figure 8.9. Each of the scenarios in Figure 8.8 is represented by the corresponding "structured scenario" in Figure 8.9.

FIGURE 8.9
Structured Scenarios from Figure 8.8

Operator	Summation By	Operand A	Operand B
1. Comparison	Time Period	Financial Plans	Units Sched/wk
2. Comparison	Line/collection	Financial Plans	Units Sched/wk
3. Comparison	Percentage match	Style operations	Manuf Category
4. Comparison	Percentage match	Operations/equip	Style or type
5. Input	6 weeks prior to delivery	Style and units	ShortTerm schedule
6. Input	x months prior to delivery	Style types and units	Long Term schedule
7. Input	Style estimates	Long Term and Short Term schedules	
8. Delete Input	By week-to-week Plant-to-plant	Style and units	Short/Long TermPlans
9. Delete	Style and units	From Plans	
10. Comparison	Percentage orders	Delivery Dates -6 months	Actual Dates Shipped
11. Comparison + 6 months	Percentage orders	Delivery Dates	Scheduled ShipDates
12. Comparison	All plants	Units produced last 6 months	Units to produce next 6 months
13. Difference	Units/wk	Units Ordered -next 6 months	Units Scheduled
14a Select	Next 3 months	Styles - units	For Raw Material A1, A2...
14b Multiply and Sum	For Raw Material Ai	Units/style	Quantity Raw Mat. Req'd

FIGURE 8.9 continued

15a Select	Week of ETA to ETA +4	Style-units	Raw Mat.Ai
15b Move	For 4 week period	Styles effected	Move to 4+ weeks into future
15c Comparison	For each Order	Scheduled shipping date	Collection Deliv. date
16a Select	Next 6 months	Scheduled delivery date for Customer #1.	
16b Select	For selected orders	Styles and week of delivery	
16c Comparison	Each order Order	Latest style Wk of deliv.	Delivery Due Date

8.6.3 Analysis of Structured Scenarios

The analysis of the structured scenarios is important because:

1. The "structuring" process is a key step in the building of a DSS(Gorry & Krimland 1983).
2. The structuring process links the scheduler's knowledge to the DSS paradigm.
3. Each structured scenario is a defined requirement for future scheduling system solutions.

8.6.4 Detailed Analysis of Sample Scenario

A specific scenario from Figure 8.8 is analyzed in detail. i.e. scenario 20 from: "A competitor is laying off experienced staff - should we hire any of these workers?" The detailed analysis of the scheduler's processes is illustrated in Figure 8.10 entitled "Sample Detailed Scenario Analysis". This analysis of this example led to the definition of the following Scenario Analysis Outline(SAO) to describe the analysis:

Scenario Analysis Outline:

1. Problem or opportunity
2. Primary area of analysis
3. Secondary areas of analysis
4. Conclusion formulation
5. Conclusions
6. Specifications

This SAO identified that the scheduler's knowledge includes the ability to assess opportunities (not only problems). In this respect the knowledge categories identified in section 8.5 must reflect knowledge categories related to the assessment of opportunities.

FIGURE 8.10
Sample Detailed Scenario Analysis

SCENARIO

A competitor is laying-off experienced staff - should we hire any of these workers?

A. ANALYSIS

1. Problem or Opportunity: Opportunity
2. Primary Area of Analysis: Comparison of Labour Requirements vs Existing Level
3. Secondary Areas of Analysis:
    1. Experience of available workers.
    2. Capabilities of available workers.
        - operation types and equipment types used
        - experience with style types and materials
        - efficiency achieved on average
    3. Low efficiency workers in existing plants.
    4. Comparative efficiency of existing workers in operation types of available workers.
    5. Historical problems related to operation types in available workers.

4. Conclusion Formulation:
    1. Labour shortage/surplus by week for next six, twelve months.
    2. Identification of worker types (by operation types) where existing efficiency is lowest or below a predetermined threshold and approximate number needed.
    3. Identification of specific operation types historically requiring upgrading.

5. Conclusions:
Yes, hire 10 workers with experience and good efficiency for operation types 6, 10, 66, 99.

6. Justification:
    1. Plant 2 requires 4 sewers (operation types 6, 66) for 6 + months.
    2. Efficiency is low in operation type 10 in Plant 3 - 3 workers.
    3. Historically operation type 99 has quality and efficiency problems.

Another important observation from the detailed scenario analysis is that historical situations, i.e. problems (or opportunities), are important to the evaluation of each future scenario if, historically, problems or opportunities have been of a significant nature in the management of the domain.

Further analysis of this example illustrates another classification of the scenarios by source of initiation or by reason for the scenario is illustrated in Figure 8.11 entitled "Classification of Scenarios By Reason". This classification illustrates the importance of the scheduling personnel being able to respond to requests for information from external management in all other areas. It also identifies that in the case of sales forecast changes, fabric delivery changes, and changes in capacity, schedulers also must prepare reports of different kinds. Within the scenarios identified, those that are internally generated relate primarily to a decision within scheduling that a delivery problem is apparent and thus a schedule needs revision. The second activity initiated within scheduling is that of adding a new style or collection of styles into the schedule. This concept is consistent with the common understanding of scheduling and its interrelationship with external departments (Fox 1986, Peterson 1987).

Figure 8.11
Classification of Scenarios by Reason

A.	Externally Generated Scenarios	
1.	Management request	1, 2, 10, 11, 12, 13, 20, 21
2.	Marketing-Sales Request	16, 17, 18
3.	Sales Forecast Changes	7, 23
4.	Fabric Changes (delivery)	14, 15, 19
5.	Production, Distribution	24, 25, 26
B.	Internally Generated	
1.	Delivery Problem apparent - Schedule needs revision	8, 9
2.	Addition of a new style to be scheduled	3, 4, 5, 6, 22

It follows from the illustrations of Figure 8.10 and 8.11 that within the history of any organization there are incidents of a critical nature that experienced personnel are aware of. Historical critical situations must also be represented in the knowledge base. By implication if historical critical situations are represented so must historical opportunistic situations be represented in the knowledge base also.

Several of the scenarios involved the use of data and information in the manufacturing corporate data base that would normally be the responsibility of other departments, i.e. production capacities, customer orders, etc. In this respect the importance of the integration of the data base with the decision support scheduling system is highlighted and emphasized. This is consistent with the representation of the data base/knowledge base with the integration of the other elements of the scheduling knowledge base as identified in this section.

8.6.4 Summary of Conclusions on Scenario Analysis

I believe the foregoing analysis of scenarios is an important step in increasing the field of knowledge of what scheduler do, how they solve problems, how they assess opportunities, and correspondingly, what the system tools must do to help them be more productive. To the extent that the system tools would help them make better decisions the resulting system would be a DSS. More specifically I concluded the following:

1. Most, if not all, of the original scenarios can be

converted to a "Structured Scenario", that suggests a more precisely defined set of requirements that could lead to the development of system solutions to facilitate the scheduler's analysis of each scenario.

2. The analysis of some scenarios is a multi stage process that relies on the scheduler's knowledge of the related cause and effect relationships(Figure 8.10), and includes primary and secondary analysis.
3. The multi stage nature of the scenario analysis, and its dependence on the interim comparisons or decisions suggests that the scheduler and the system must be tightly integrated.i.e. the system must conform to the scheduler's understanding of the situation, and all its structures.
4. The knowledge possessed by the scheduler in conducting the scenario analysis is critical in determining the direction that the analysis follows once begun.
5. Once the scheduler determines a specific direction, the required tasks often involve mathematical and logical operations. These types of operations appear to be candidates for the development of specific tools.
6. The analysis of Cases I and III identified that the scheduler will follow repetitive analysis processes for similar situations. Since these analyses are similar and can be assisted by specific tools, the potential exists for the scheduler to use combinations of tools that can be initiated by specific conditions. If these conditions can be defined then the decision process can also be defined in the form of:

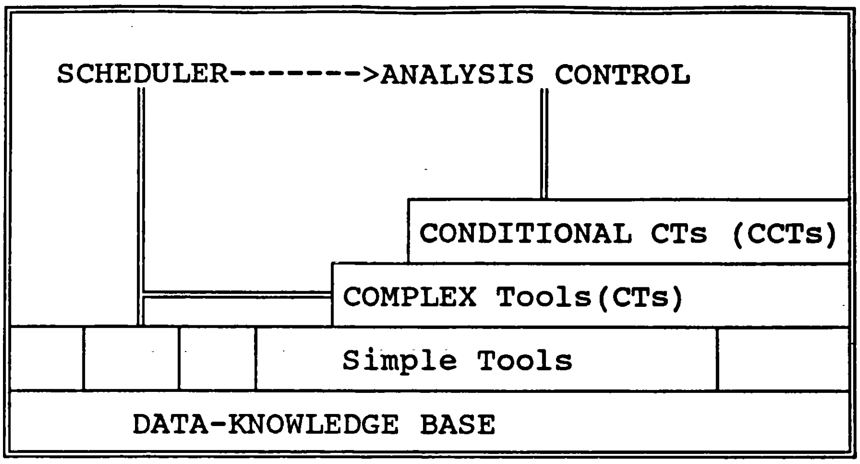
   IF Condition A1: then Execute Process P1.

7. The development of such a Scheduling System would evolve from a simple DSS with a few tools, like CAASS, to successive versions with more tools, followed by combined tools(Complex Tools). As the conditions for the use of a Complex Tool became clear simple condition invoked Complex Tools would evolve(Conditional Complex Tools). Figure 8.12 illustrates the evolutionary architecture proposed.

8. The evolutionary development of the system through increasingly complex CCTs to make decisions on which tools to invoke, followed by entire sequences of CCT analyses each invoked by the system, would be in the direction of representing more of the scheduler's knowledge, tasks and expertise in the system. Thus the system would evolve towards a growing replication of the experts knowledge and structured analysis processes. Thus the system evolves from a DSS to an Expert Scheduling System.

Figure 8.12

Evolutionary Scheduling System Architecture



9. The development methodology suggested by this discussion is consistent with the prototyping and evolutionary design of traditional DSS and ES literature(Alter 1981, Hayes Roth 1983).

10 The methodology employed by myself in the evolutionary design of the foregoing architecture made me aware of the realization that my role was both designer and scheduler. This led me to the question: Should the Scheduler be the designer ? DSS and ES literature support this direction. How could the Scheduler become the Designer ? The initial answer I found in the basic concepts of the Lotus 1-2-3 Spreadsheet system with its Macro-keystroke saving feature. This direction then led me to conclude that such a macro definition facility would allow the scheduler to design his own Complex Tools(CTs), and the Conditional CTs(CCTs).

11. The methodology proposed thus consists of the evolution of a Scheduling DSS to an Intelligent DSS to an Expert Scheduling System.

12. With respect to the Hypothesis testing of this study the study of the Scenarios suggests that the resulting system architecture would in fact be supportative of the two hypotheses below, namely,

H6: The use of Expert Systems Technologies results in better GMI scheduling systems, and

H7: The merging of DSS and ES technologies results in better(useful and usable) Garment Industry Scheduling Systems.

8.7 DECISION MAKING AND EXPERTISE

During the analysis of the three cases I became curious as the nature of the relationship between decision making, knowledge and expertise, with specific reference to a scheduler.

Upon reflection I concluded that, when an expert makes a recommendation, a judgement or a conclusion on a particular question, opportunity or problem, in essence, he is going through a decision making process. In Carlson's(1978) terms the Intelligence phase is that of collecting the relevant information of the situation and analyzing it. The Design phase is that of formulating the optional responses, if any, and the Choice phase, is that of selecting what appears to be the best option and presenting it as the recommendation or judgement.

The differentiation between the performance of an expert and the performance of a novice can be seen to be related to the quality of the decision making processes. More specifically, if the decision making process is dissected into its individual and distinct steps, then the performance of the specific steps can be related to the performance of an expert versus a novice. If the decision processes of Intelligence, Design and Choice are enhanced by the use of appropriate system tools then the quality of the decision will be enhanced. The enhancement of the phases of Intelligence, Design and Choice, can begin with the analysis of how an expert views and conducts these tasks and what tools he would like to have to further enhance these phases.

The characteristics of the systems of Cases I and III were compared in the area of the decision phases of

Intelligence, Design and Choice. This analysis is illustrated in Figure 8.13.

The Case III included several improvements including:

1. The graphical representation of the many numbers represented in the Case I spreadsheet.
2. The clear list of unallocated WOs and the use of the colour red to show a late WO, focused the scheduler's attention on the specific problem easier then with the Case I spreadsheet.
3. The Case I system required review of two sources to determine if Fabric deliveries were a problem. The Case III system integrated the fabric delivery date with the customer delivery date into a production window of time in which to make the product.
4. The process of designing possible solutions in Case III used the mouse with immediate feedback if the action was successful i.e. no more unallocated or red WOs. In Case I the keyboard cursor arrows had to be used to select the WO to remove, the number re-keyed, then cursor to the week to be tested to see if the problem could be eliminated, re-key the numbers, and re-calculate the spreadsheet(5-15 minutes).
5. The Choice of best option in Case I became that of the first one found, since each option evaluation cycle required several keystrokes(12-30) and 5 to 15 minutes. In Case III the Choice decision was made after attempting many options at the rate of 1-5 per minute.

From this analysis I concluded that although both Case I and Case III systems had very similar underlying system structures for capacity by SAMs and the loading of WOs by SAMs, the design representations of Case III were superior in the specific areas of:

1. The replacement of the WIP(days) and Days loaded/wk numbers by graphical representations of rectangles fitting within larger rectangles and colours of red, green,and blue,
2. The replacement of the keyboard arrows and keys by mouse hand movements,
3. The integration of the constraints of two spreadsheets for fabric delivery into the same single graphical presentation.
4. The manual ranking and batching of customer orders into work orders was replaced by the batching command,
5. The manual loading of WOs into weeks was replaced by the auto load command,
6. The combined decision processes or phases of Intelligence, Design and Choice were 60 times faster with the Case III system.

Figure 8.13

Design Representations for Decision Phases		
Decision Phase	Case I	Case II
Intelligence to identify a problem. Key indicators displayed	Lotus Spreadsheets Plant Load (Figure 5.4) Fabric Delivery Summary(Fig 5.6) Days Loaded/wk Cumulative WIP days Fabric Delivery Plan	Graphical display (Fig 7.6) Unallocated Work Orders, or "Red" WOs
Design soln option 1. Move W.Order	Move style units loaded to alternate week & evaluate 5-15 min/cycle	Re-arrange WOs with mouse cmd 5-60sec/cycle
2. Try Overtime	Move to Capacity defn increase Hrs/Day 7-17 min.cycle	Change hrs/day 30 sec/cycle
3. Change Fabric ETA.	Review fig 5.x Move units (1) 7-17min/cycle	Change fabric, availability, 30 sec/cycle
4. SubContract	Add new plant, load plant 1-2 hours/plant	Add new plant load WOs 3 min/plant
Choice	Choose first move that satisfies delivery problem. If no easy solution elevate to Scheduling Committee	Choose first move that fits with no red.
Min cycle time	5 minutes	5 sec
Max cycle time	2 hours	3 minutes

8.8 CHAPTER SUMMARY

The comparisons of the three cases with each other and with the DSS, ES and ESS literature support many of the established principles. The DSS exceptions identified are important since they question the validity of the corresponding principle, and highlight potential areas for further study.

The ES exceptions identified are significant, and a reasonable explanation is required. Although, the ES methodology appears reasonable the representation needed for the scheduling problem appear to be different than those of other types of expert systems.

The ESS field is so new that no broad principles can be established. While the similarities of ISIS, FAMS and CAASS may suggest a guiding principle, time and further research is required.

The exercises to document scheduling knowledge at a detailed level prior to knowledge representation, resulted in the identification of several relationships and conclusions that had not been explicitly stated before. These conclusions are important because they suggest requirements and guidelines for future scheduling systems.

The comparison of the Decision phases of Intelligence, Design and Choice between the two successful systems of Cases I and III, illustrated how design representations can increase a schedulers' decision processes by 60 times.

PART IV: CONCLUSIONS

CHAPTER 9 - A GENERAL ARCHITECTURE FOR SCHEDULING SYSTEMS

9.1 INTRODUCTION

This section describes the synthesis of the foregoing research into a broad architecture which defines a structural approach to the solution of garment scheduling problems. The approach and architecture proposed is seen as sufficiently broad that its principles and concepts could conceivably be utilized in the design and development of domain specific expert systems.

The description of this architecture is considered to be hierarchical or top down. Initially the broad philosophy is described followed by illustrations and subsequently specific examples of the many concepts included in the architecture are presented.

9.2 THE THREE-TIER ARCHITECTURE

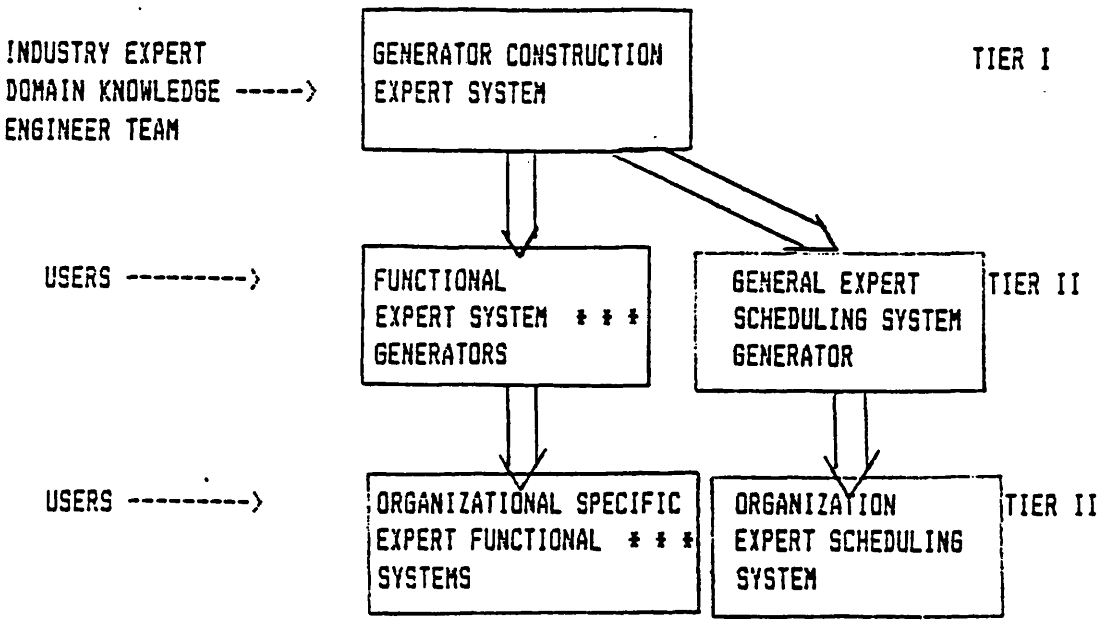
9.2.1 Overview

The proposed architecture is seen as a three-tier structure. This structure is illustrated in Figure 9.1. As illustrated in Figure 9.1, the fundamental knowledge engineering function is performed by a highly skilled "expert" application specific knowledge engineering team. This team is visualized as being composed of industry specialists or application specialists who have considerable experience and who themselves may be experts in specific domains within which the organization functions.

This expert knowledge engineering team utilizes the first tier of the three-tier architecture. The first tier consists of an expert system which assists the knowledge engineering team in developing the second tier or "functional expert system generators" (FESG). The FESG's systems are developed for each functional area within the organization. One such functional area is that seen as production planning and scheduling. Thus there would exist a FESG for the scheduling area which would be called "general expert scheduling system generator" (GESSG).

Figure 9.1

Three Tier Architecture



The third level of the three-tier architecture consists of specific organizational expert systems each performing in a particular functional area of the organization. In this respect, a given organization would have their own version of the expert scheduling system. These "organizational expert functional systems" (OEFS) would exist for each function that the organization has installed a corresponding generator at the second tier of the architecture.

The tier one system level is utilized by the expert knowledge engineering team. Tiers two and three of the architecture are utilized by individuals within the user organization. The description of each tier level in detail is facilitated by beginning with the lowest level or tier three systems.

9.2.2 TIER III:

The specific expert systems that operate at the tier three level have been named "organizational expert functional systems" (OEFS). At this level exist expert systems which are similar to those that are being developed currently in a number of organizations. Included in this set of expert systems is the manifestation of the scheduling expert system which is envisaged as that which would address the garment scheduling problem.

This expert scheduling system is seen to embody all of the concepts described in previous sections regarding the requirements and operation of such a scheduling system. These specific concepts are illustrated in more detail subsequently.

Expert systems at this organizational functional level are generated by the expert systems at the Tier two level. From the viewpoint of the organization and its users, specific departmental or functional users would be the primary users of each such system. In this respect, the scheduling department would be the prime user of the expert scheduling system.

9.2.3 TIER II:

The second tier of the general architecture contains specific "functional expert system generators" (FESG's). These expert system generators are designed primarily to perform the function of a specific functional knowledge engineer. In this respect, they interact with the organization's user group in a specific functional area as well as representation from the senior management policy group in order to carry out a function similar to a knowledge engineer in a given functional area of an organization.

In the instance of a "general expert scheduling system generator" the function is that of scheduling and the purpose of this scheduling generator would be to emulate the knowledge acquisition and knowledge engineering functions which would be performed by a knowledge engineer in the process of developing an expert scheduling system at the tier three level.

I believe that such an expert system generator is not only feasible but shortly realizable. This belief is based upon numerous conclusions within this dissertation that identify the relationship between organizational specific policies, objectives, preferences, and practices with clear representations of expert system manifestations. In addition, the fundamental nature of scheduling systems within a given industry are constrained in their variability but do differ from organization to organization. Given that the basic product development cycle and the fundamental physical model is represented in the expert system generator level (Tier II), the rules that a knowledge engineer would utilize to select the specific representation of the organization's physical model can be easily obtained in a simple dialogue with users.

Similarly, different representations of performance measures which dictate the specific type of "scheduling activity process" can also be related to a user dialogue defining objectives, marginal rates of substitution between objectives and policies. The key or most important level of the proposed architecture is seen as level two. This is because the functional expertise in designing expert systems in the functional level (Tier III) must be represented in the Tier II level. The detailed components of the general expert scheduling system generator are illustrated in more detail in subsequent sections as an example of the general architecture involved in "functional expert system generators" (FESG's).

9.2.4 TIER I:

The first tier of the architecture is embodied in a single expert system called the "generator construction expert system" (GCES). This expert system is seen to facilitate the development of the specific Tier II expert system generators. This GCES can be seen to represent and emulate the skills of a senior knowledge engineering team who have previously developed expert system generators at the various functional levels embodied in Tier II. In this respect, given the expertise and knowledge of such a senior-expert group, it is envisaged that a combination of their experience, skill and expertise would be realizable in an expert system representation. It is visualized that this expert system will contain functional specific representations related to the types of options which would be used at the level two expert system generator level. In this respect, when the senior knowledge engineering team is in the process of developing a level two general expert scheduling system generator, it would utilize that portion of the GCES which represents structures, control modules, and other representations that would typically be found in level two expert systems.

Although a theoretical foundation has not been found to exist for the classification of expert system generators envisaged in Tier II, I believe that such a theoretical concept is an inevitable evolution of the current state of knowledge engineering concepts and practice. Once such a theoretical foundation exists for the generation of expert systems generators at the Tier II level, then it is inevitable that Tier I expert systems will become reality.

Although it could be argued that today's expert systems development tools and expert systems shells are synonymous with the general generator construction expert systems envisaged in Tier I, I believe that the GCES concept is different in at least the following concepts:

1. The Tier I GCES is visualized as being functionally related to a particular type of industry or general application area such as manufacturing and thus directly related to the functions that are embodied in the Tier II level.
2. The general expert system development tools which exist today are seen to be needed in order to develop the Tier I level system envisaged.
3. Conceivably in the future, a gap between general expert system development tools and the Tier I expert system envisaged in this architecture may be further divided with the emergence of another level of expert system which generates those envisaged as being the Tier I level in this architecture.
4. The fundamental difference between the type of expert systems proposed in this architecture and existing expert system development tools can be seen in the use of such existing expert system development tools for the construction of a wide variety of expert systems in many application domains. The theory or philosophy behind the development of expert systems within the proposed three-tier architecture is that such expert systems are related not necessarily through generic representations so much as by their specific domain, function, application, industry, and structural organization. Clearly within this concept, considerable future research is necessary.

9.2.5 User/Organizational View

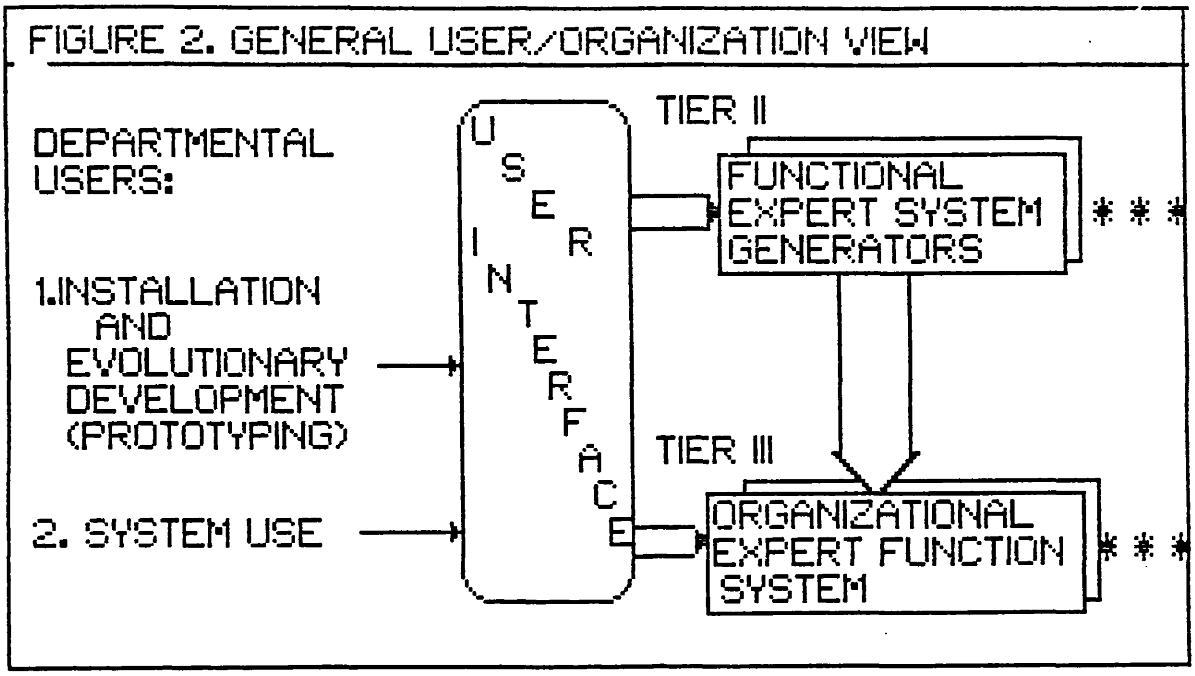
The use of the level two and level three expert systems by individuals within organizations is illustrated in Figure 9.2. A fundamental concept within this architecture is that level two and level three systems are transparent to the user. Thus individual departmental users addressing the expert system initially are led through a dialogue to install the system or perform set-up activities. Subsequently, the same facilities exist for future prototyping, or evolutionary development of the system. This fundamental requirement as defined in the review of requirements is seen as extremely important to the architecture.

Throughout the previous documented research, the concept of prototyping, evolutionary development, plateau of comfort, and other similar concepts have re-emphasized to this researcher that this fundamental cognitive reality must exist in any future system architecture.

Upon completion of the set-up or evolutionary iteration, the system is available for use, again transparent to the user. The use of the system is involved with the third level of the three-tier system architecture. The user interface and the general system architecture concepts are illustrated now in reference to the specific garment scheduling problem.

Figure 9.2

General User/Organization View



9.3 SOLUTION OF THE GARMENT SCHEDULING PROBLEM

9.3.1 Introduction

In this section, the specific manifestation of the three-tier system architecture is illustrated as to its use in the solution of the garment scheduling problem. This discussion is organized, firstly, and in most detail, with reference to level two and level three systems. Subsequently, considerations in the design of the level one system are also presented. Clearly, this is appropriate in that levels two and three are function or application specific whereas level one is industry specific.

9.3.2 Scheduling User/Organization View

From a scheduling department viewpoint, the three-tier system would be viewed as illustrated in Figure 9.3. The scheduling users which normally would be composed of the scheduling department and one or more senior managers would participate in the initial system installation or "set-up". Subsequently, the scheduling department would commence use of the system and would, over time, develop additional requirements, and in general, evolve into more sophisticated usage of the system. As new features and concepts are accepted by the scheduling personnel, these concepts would be embodied in future prototypes or evolutionary manifestations which would be redefined to the level two expert scheduling system generator. The resulting new expert scheduling system would reflect the expansions and modifications defined by the evolutionary development activities.

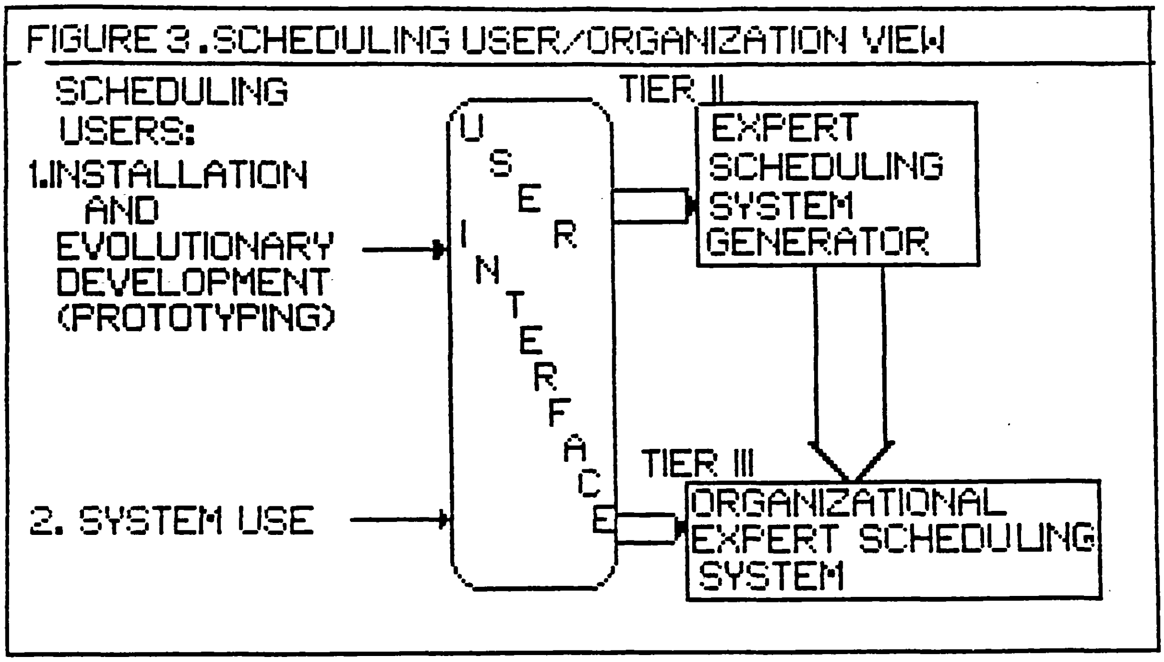
The facility to accomplish this evolutionary development is one of the fundamental challenges in the design of this architecture. Clearly, to attempt to envisage all possible prototyping directions resulting from evolutionary development is extremely ambitious. However, from my analysis of the problems and experience in developing systems through the prototyping methodology it is believed that not only can such a direction be begun as a result of this thesis, but given the appropriate level two and level one expert systems such a direction will in fact be achieved. In addition, the problem of foreseeing all possible situation organizational specific factors can be further minimized by viewing the architecture as pertaining to a particular type of industry. Within an industry it has been my conclusion that methods of production planning and scheduling do have considerable similarity across companies. Where similarities do not exist, they can clearly be related to fundamental organizational differences or policy differences.

An example of this can be seen in a basic garment philosophy in manufacturing. In the event an organization is fashion oriented than their specific manufacturing philosophy is usually to "make-to-order". In such an environment the scheduling activities are based upon forecasting as a result of financial plans rather than seasonal and historical analysis of trends. In addition, given such financial plans these are subsequently defined by market segments, seasons or period within the year, and eventually into specific collections and product classifications. This structure then lends itself to specific scheduling procedures which have been identified in the prior section on review of system architecture requirements. Continuing the example, a comparative organization which is not in the fashion business, but rather in the repeat or annual non-seasonal type of business activity, can be seen to follow the manufacturing philosophy of "make-to-inventory". Following such a philosophy, individual policies are related to the "inventory turns", "customer lead time/delivery time targets", "customer service level targets", and other organizational objectives related to an "order from inventory" philosophy. In scheduling activities related to this type of business activity, scheduling processes can be based on forecasts computed not only from financial plans, but from historical trends utilizing techniques such as exponential smoothing. Resultant forecasts are then used to identify required inventory demand to service customer orders. The capacity planning problem when related to finished goods inventory policies are considerably easier to plan than the "make-to-order" philosophy.

This illustration could be carried out in detail but to the extent provided, the illustration is sound. Clearly, the identification of the relationship between an organization's philosophy of business, its organizational structure, its long term and short term goals, the relationships exist which result in defining specific policies and procedures at the detailed scheduling activity level.

Figure 9.3

Scheduling User/Organization View



9.4 TIER III EXPERT SCHEDULING SYSTEM DESIGN

At the Tier III level of the architecture, the specific expert scheduling system architecture is represented in Figure 9.4. This system architecture is composed of the following modules:

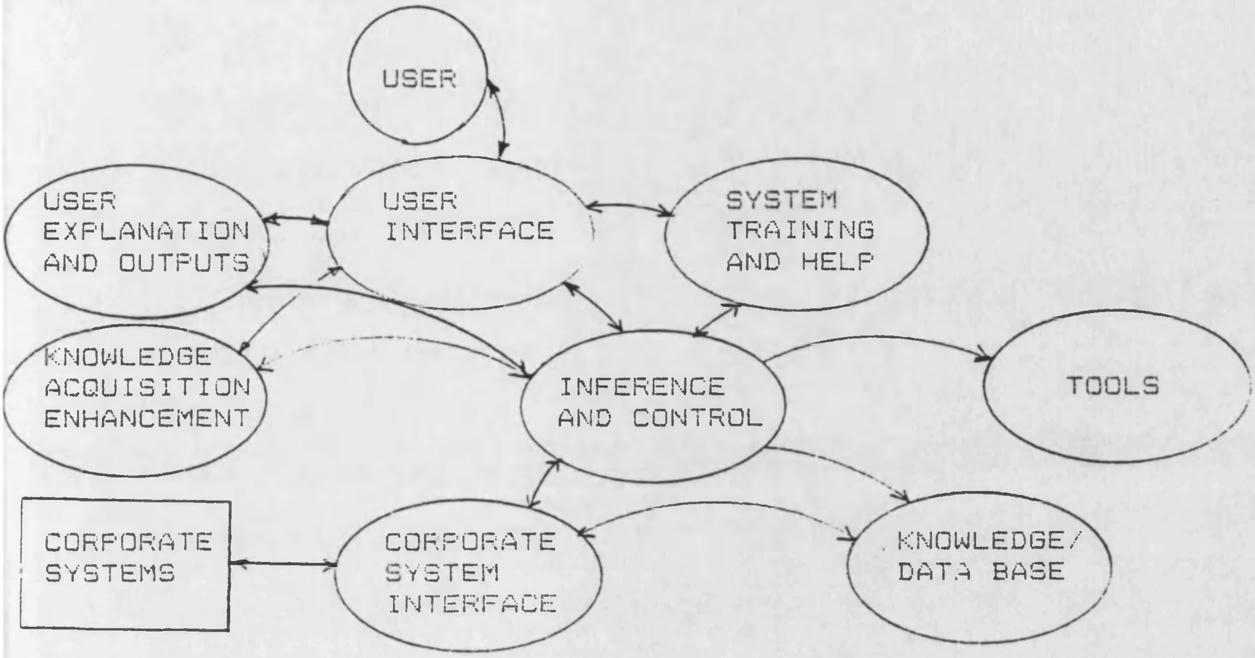
1. User interface
2. System training/help modules
3. Knowledge acquisition enhancement/system training
4. User explanations and outputs
5. Knowledge base/data base
6. Tools
7. System interfaces
8. Inference control module

Each of these modules is described as follows:

User interface. Utilizing the latest graphical and non-keyboard input devices along with high resolution screens and high resolution hard copy outputs. The user interface follows conventional expert systems practice of controlling all user system dialogue. System training/help modules. This module allows the user to request training assistance at the beginning of a new user's experience with the system. It allows the user to develop and use the system without modifying or in any way affecting the "live" system. The help modules offer the same function as traditional help modules in computer systems (i.e. By requesting assistance using a "help key", information concerning a given module would be presented.) Knowledge acquisition enhancement/system training. Following conventional expert systems design this module allows the scheduler to inform the system of knowledge which is relevant to the existing structure of the knowledge base and data base. It does not provide the function of the level two expert system generator. It assumes the knowledge base and data base is structured without change. User explanations and outputs. This module is the primary output module in the system. Outputs, whether automatic or requested by the user, are automatically generated with appropriate explanations where inferences have been made. In this respect, the system is visualized as producing very few, if any, outputs that are not accompanied by brief explanations or, in some fashion, presented in the form of completed reports within textual presentations which embody the specific requested information.

Figure 9.4

Expert Scheduling System Architecture (Tier III)



This is seen as a progressive evolution from conventional MIS and DSS systems whereby computer outputs are seen primarily as simple tabular or graphic information without explanatory text. This is in contrast to conventional system design methodology which fails to recognize that most, if not all, reports prepared by supervisors and managers do, in fact, contain appropriate narratives to explain any exhibits which have the tables or graphs which typically come out of the computer systems. Knowledge base/data base. This concept represents the belief that in future, knowledge and data will be integrated in the form of knowledge and data base management systems. I see the representations as primarily based on entity-relationship data base management technique incorporated with object oriented programming. For purposes of this discussion, all of the data which is required for the operation of the expert scheduling system is assumed to be contained in this integrated knowledge/data base system. The knowledge representation is seen to correspond to the previous conclusion that in this application the knowledge base represents a "shadow" or parallel to the conventional data base organization for manufacturing applications. Tools. The tools module in the Tier III expert scheduling system contains a variety of individual modules and structures that can be utilized to perform specific operations research, simulation, decision support and similar standard "off the shelf" routines. In this respect, the routines to implement the various algorithmic and heuristic solutions for activity scheduling and dispatching would be represented in this module. System interfaces. This module is organizational specific in that each organization will have potentially a different type and degree of automation with utilization of a variety of hardware architectures, and software packages. This module is seen to contain a variety of routines which cover the spectrum from simple microcomputer file I/O, to sophisticated data management system routines allowing for the retrieval and updating of data in the company's corporate data base systems. Inference control module. Following conventional expert systems architecture this module includes the control structure which is activated by a variety of stimuli including specific user interaction. Other activities within the system would be initiated by a clock-calendar review function and external corporate system activity. In addition, the execution of specific expert system module to implement problem diagnosis and solution, user information requests, general schedule management and agenda processing, automatic schedule regeneration, user/management report recommendations, and the execution of decision support tools as requested by users are some of the functions which are carried out under the control of this module. The knowledge programming requirements of this module are seen to be non-trivial and it is anticipated that a more sophisticated knowledge engineering development tool would be essential for the implementation of these functions.

The functional requirements to be represented in this expert scheduling system are related specifically to the requirements identified in the prior section. Briefly, these include the following:

1. Problem prediction. The system will be able to identify potential delays and risk situations in the existing schedule and as a result of a failure of the expected events to occur. In this respect, Fall's (1986) work on evidential reasoning is seen to be implemented in this system.
2. The system will be able to identify the critical information from the potentially vast amounts of non-critical data in its knowledge/data base. This function is the manifestation of the corresponding requirement identified for the intelligent management of detail.
3. The system will monitor the relationship of ongoing schedules and completed production to higher level forecasts and financial plans and signal trends of developing variances.
4. The system will accept the judgement of experts and senior management as well as appropriate minor policy and new expertise input. In addition, the system will be capable of accepting imperfect and imprecise data and, where necessary, rely on default values.
5. The system is seen to operate on its own agenda utilizing internal calendars and clocks to determine its operating cycle for preplanned daily, weekly, monthly and annual cycles.
6. When an existing schedule has been modified or sufficient variation has occurred as a result of other events, the system will automatically reschedule and

notify appropriate management and scheduling personnel.

7. Following the concepts embodied in various scenarios identified in a previous section, the system and the scheduler or senior management personnel will communicate in a problem solving/opportunity assessment dialogue with conclusions of appropriate solutions and actions based on concepts of intelligent decision support systems.

9.5 TIER II: GENERAL EXPERT SYSTEM GENERATOR

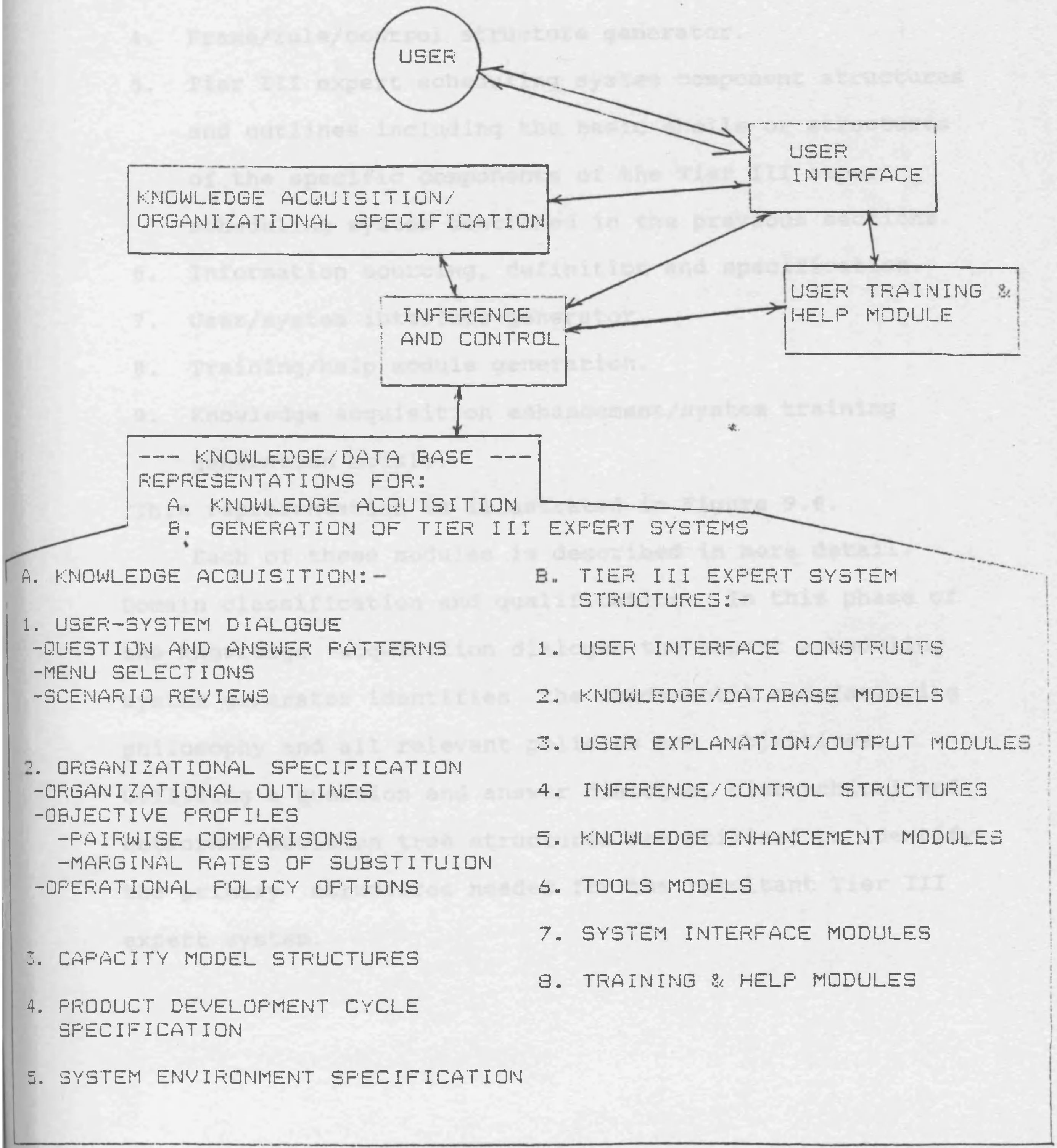
The second level of the proposed architecture is the most critical level within the system. Through its generation capabilities expert scheduling systems at the third level will be created. The expert system for the generation of Tier III systems embodies a vast and wide knowledge base representing the various types of organizational philosophies found within a given industry for a given application such as scheduling. In addition, the representation for various forms of user interfaces, knowledge/data bases, system interfaces, tools, and similar manifestations of the other Tier III system components are represented in the knowledge base of Tier II system generators.

The primary function performed by the general expert scheduling system generator (GESSG) is that typically performed by a knowledge engineer in developing an expert system. Initially, the function is one of knowledge acquisition whereby the system emulates the knowledge acquisition stage of a knowledge engineer. With respect to the scheduling domain, the information requested from the user is of a structural and policy nature. The second activity undertaken by this expert system generator is that of knowledge engineering whereby the solicited information is utilized to formulate the specific manifestation of the Tier III expert system. This architecture is illustrated in Figure 9.5.

Figure 9.5

General Expert Scheduling

System Generator Architecture (Tire II)



9.6 THE GENERATION PROCESS IN DETAIL

Within the Tier II general expert scheduling system generator design the following primary components exist:

1. Domain classification and qualification.
2. Domain definition and specification.
3. Problem definition/specification.
4. Frame/rule/control structure generator.
5. Tier III expert scheduling system component structures and outlines including the basic shells or structures of the specific components of the Tier III expert scheduling system described in the previous sections.
6. Information sourcing, definition and specification.
7. User/system interface generator.
8. Training/help module generation.
9. Knowledge acquisition enhancement/system training generation module.

This representation is illustrated in Figure 9.6.

Each of these modules is described in more detail.

Domain classification and qualification. In this phase of the knowledge acquisition dialogue the expert scheduling system generator identifies the fundamental manufacturing philosophy and all relevant policies and objectives. Utilizing a question and answer dialogue, hierarchical and networked decision tree structures are utilized to identify the primary structures needed for the resultant Tier III expert system.

Rules within this module are of the type:

"IF (classification question and answer)

THEN (add modules X1, X2,...)

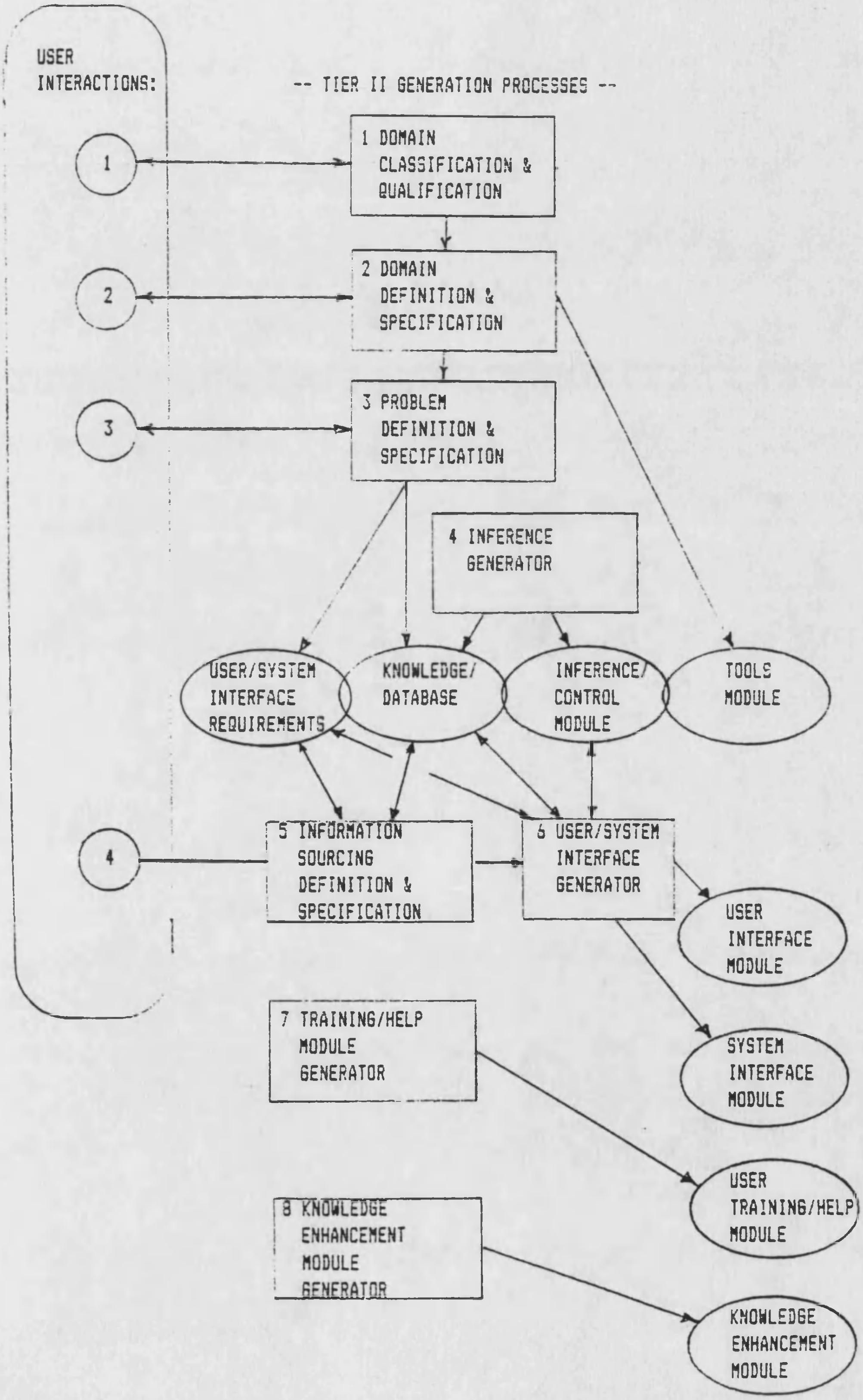
TO (subsequent knowledge acquisition and representation

steps as identified below)

Figure 9.6

The Generation Cycle

Generation of Tire III Expert Scheduling System



In this respect this module is seen to embody the knowledge of which subsequent questions and structures must be defined based upon the primary identification of the domain classification and qualification. Domain definition and specification. As a result of the prior module identifying the basic philosophy, policies and objectives of the organization, this module acquires more detailed information related to the initial defined structures. In addition, this module is seen to request definition of the physical model and operational policies including the physical representation of the manufacturing operation. In this respect, the representation of the product cycle, the capacity model with options and policy and preferences, the definition of the flow of various key transactions related to the discussion by Fall(1986) on evidential reasoning, acquisition related to the specific objects of materials, products, vendors, customers, and all other necessary physical entities would also be required in this module.

Problem definition/specification.

This knowledge acquisition module is the manifestation of the knowledge representation scheme identified in several sections of this research. Specifically, this structure requests from the user the identification of problems, decisions, and critical events related to the concepts described in previous sections and referred to as the problem knowledge base. This module is seen to be fundamental in embodying the power of the problem prevention, expert decision making paradigm. Frame/rule generator. This module is the beginning of the "knowledge engineering" activity. Given the foregoing knowledge acquisition stages, this module generates the specific Tier III expert scheduling system modules to implement the specific scheduling process determined as a result of the prior definition of the organization. This module generates Tier III components for:

- Knowledge/data base
- Control meta rules
- Tools
- User interface requirements, and MIS/DSS system interface requirements

These latter two are not yet complete.

Information sourcing definition specification.

This module is seen as the acquisition of information concerning the system environment and other applications presently in place in the organization. Within this environment acquisition module, specific system interfaces are defined and specific inputs identified as user supplied or system interface supplied. As a result of this knowledge acquisition activity additional generation can be carried out for the knowledge/data base control meta rules, user interface requirements and MIS/DSS interface requirements. User/system interface generator. Given the prior definition of the sourcing and interface environment, this module now creates specific user interface and system interface modules and the appropriate representations for their execution and operation. User training/help module generation. Given the foregoing, this module generates user training and help modules and incorporates these into the corresponding component of the Tier III expert scheduling system. Knowledge acquisition enhancement module generator. Given the foregoing definition of the system, this module generates the corresponding Tier III component to identify those knowledge representations that can be augmented directly as a means of training the expert system.

The general design of the Tier II cycle identified above resulted from my consideration of how a knowledge engineer would design a Tier III system. Given the nature of the research and the field work with a variety of companies, the natural evolution of the research into the realization that multiple situations exist in this industry, have led to the above architecture.

I also view the concepts developed in this study relating to how an expert makes decisions as being fundamental to the architecture presented. In this respect, the concepts of an expert possessing "off the shelf" questions, structures, methods, tools, designs, solutions, diagnoses, recommendations, presentation formats, and training methods all flow from that initial realization of the relationship between expert decision making, the provision of expertise and the solution of problems.

9.7 TIER II GENERAL EXPERT SCHEDULING SYSTEM GENERATOR

Given the architecture described for the Tier II and Tier III expert systems, I view the process of specifying the specific details of each module as being primarily a process of conventional expert systems development. The effort required is in excess of any individual expert system because of the necessity to identify the specific domain classification and qualification options. In addition, the mechanism of obtaining the domain definition and specification information and, in particular, the physical model of the manufacturer with its representation of the various objects, etc., further adds to the quantity of work involved in the development of such a system.

To complete the development of the proposed Tier II architecture, it is seen to require several man years of knowledge programming. Clearly, such a low level task is outside the bounds of this research. As a compromise between leaving the research at the foregoing level and carrying it forward to a full operational expert system, I included in Appendix B a number of detailed charts and examples of the various representations to further illustrate the detail involved in the foregoing architecture.

9.8 TIER I DESIGN

In the process of developing Case III, I became aware of the potential for parallel relationships existing in other functional or departmental areas within the manufacturing organization. As a result of development of architectures for Tier II level expert systems in these other functional departments, the analysis of the several functional departmental expert system generators would result in the identification of similarities and standards between each one of these functional expert system generators. In each one of these functions, within an organization, the primary knowledge acquisition modules of:

1. Domain classification and qualification
2. Domain definition and specification
3. Problem definition/specification would exist.

The design of the Tier I system would then represent those knowledge acquisition structures as part of the Tier I expert system knowledge base. Similarly, analyzing the subsequent components of the Tier II expert system generators would yield similar parallels and general knowledge representations of these. These structures would then be identified generically as well as with their specific embodiment of the knowledge required in a specific industry based on different operating and philosophical policies within that industry.

The knowledge engineering team utilizing the Tier I generator construction expert system would participate in a question and answer knowledge acquisition activity with this expert system. Utilizing experienced knowledge engineers who had designed expert systems at the Tier I and potentially at the Tier II level, these knowledge engineers being familiar with the design choices amongst different organizations would then participate in the formulation of the knowledge base identified within the Tier II level.

In this respect, the Tier I generator construction expert system is itself a manifestation of a very high level knowledge engineer.

With continued evolution of knowledge engineering technology and its increased application in commercial and other domains, I view the inevitability of Tier I expert systems becoming available for use, not only by industry knowledge engineering teams, but eventually by industry specialists. In this respect the knowledge engineering training presently required to implement sophisticated expert systems may eventually be replaced by their manifestation in the form of Tier I expert systems.

9.9 UNIVERSAL SYSTEMS ARCHITECTURE

Continued evolution of the process and cycle of the development of higher level tiers for the generation of expert systems at a lower level, which themselves generate other expert systems, leads to several futuristic concepts.

Clearly, if an expert system can be utilized by non-knowledge engineers to generate lower level expert systems, then such expert systems can also generate integrated expert-decision support-management information-data processing systems. Although the effort involved for the development of these universal system generators is extensive, especially when the number of potential organizations is considered within any industry, once the initial system generator has been created based on current known existing technologies and data base representations, the subsequent leverage in developing systems for that industry is phenomenal. Pursuing this consideration further leads to the conclusion that eventually programmers, systems analysts and perhaps even knowledge engineers will, in part, be replaced by expert systems utilized for the development of all other types of systems. This concept of the universal systems architecture is illustrated in Figure 9.7.

Figure 9.7

Universal System Architecture

INDUSTRY/APPLICATION KNOWLEDGE ENGINEER "EXPERTS"	--->	GENERATOR. . . GENERATOR CONSTRUCTION EXPERT SYSTEM	
		* * *	
INDUSTRY ANALYST- INDUSTRY EXPERT(S)	--->	GENERATOR CONSTRUCTION EXPERT SYSTEM	TIER I
USER	--->	GENERAL FUNCTIONAL EXPERT SYSTEM GENERATORS	TIER II
USER	--->	DOMAIM-APPLICATION SPECIFIC EXPERT SYSTEM	TIER III

CHAPTER 10. CONCLUSIONS AND FUTURE DIRECTIONS

10.1 INTRODUCTION

This study has provided evidence that the merging of DSS and ES technologies in GMI scheduling systems can lead to better systems than either technology by itself. In this respect "better" systems suggest more usable and more useful.

In presenting this and other conclusions, I have been guided by the works of Hillway(1964) and several Ph.D graduates from the University of Bath(Preston 1981, Atchong 1981, Cumberledge 1982, Armstrong 1979, Diggory 1983, Harrison 1984, Hitchmough 1984, Brewer 1981, Pye 1984, Sims 1978). From my study of these works, followed by my reflection on their relevance to this thesis, I have determined that this chapter should address the following topics:

1. Using Hillway(1964)'s legal analogy, the evidence for the proof of the hypothesis must be reviewed as a barrister might do in his summation to the jury. Thus I have recounted the initial focus, and linked each piece of evidence to the confirmation of the study hypotheses.
2. Leaving the legal analogy, I then review the research as a contribution to knowledge, and its value to the research, manufacturing, and Information Technology audiences.
3. The methodology and my role as the researcher are then discussed, with a realistic assessment of strengths and weaknesses.
4. The limitations of the study are presented and the many areas for future research that are suggested by these are presented.
5. Finally, I close the thesis with my personal view of this research.

10.2 CONFIRMATION OF HYPOTHESES

This study began in 1984 with the vision that the Garment Manufacturing Industry(GMI) scheduling problem could be solved by employing Decision Support and Expert Systems technologies. In this thesis the vision was expressed as the research hypotheses:

H5: The use of DSS technologies results in successful GMI scheduling systems. (Studied in Cases)

H5: was the foundation of Case I and is reported in Chapter 5, and for Case II, in Chapter 6.

H6: The use of Expert Systems Technologies results in successful GMI scheduling systems. (Studied in Literature review and Case III)

H6: was the foundation for initiating Case III, described in Chapter 7.

H7: The merging of DSS and ES technologies results in successful(useful and usable) Garment Industry Scheduling Systems. (Main Hypothesis of this study)

When I began this study in 1984 the scheduling problems in the Case I company were significant and had not been solved by the use of traditional MRP systems. Within the GMI no new solution approaches were evident. Through the application of the DSS paradigm in Case I, a usable and useful scheduling system solution evolved. This success was the result of the efforts of an experienced and enthusiastic scheduler, a programmer, and myself, and the support of the company management. This positive conclusion required 24 months to become apparent.

In Case II(1988), a project with the same objectives as

Case I failed because the DSS paradigm was not adhered to and project and organizational support was absent. This negative conclusion was accepted after 11 months of effort.

In both Cases I and II, the analysis of the cause-effect relationships supported the hypothesis that implementation of the DSS paradigm led to successful scheduling systems.

Case III(1987-1990) began as a test of the hypothesis that the ES paradigm would lead to successful scheduling systems. In stage 1, the ES methodology of prototype development, to replicate the scheduler's expertise in an expert scheduling system was attempted. The prototype project was successful in developing and demonstrating promising concepts such as the "expert tools", that embodied the expert's knowledge and methods into powerful system functions. The prototype project ended when the graphical user interface(GUI) of the Lisp language was determined to be inadequate. Following accepted ES methodology(O'Farrell 1986), a "delivery system" was developed based on the prototype, but with significant enhancements in the "expert tools", and the GUI. The selection of the Macintosh, and the Pascal language, was a successful environment for this development.

The result of the Case III project was a successful scheduling system that we called CAASS(for Computer Assisted Automatic Scheduling System). Analysis of the project methodology and the resulting CAASS system determined that elements of both DSS and ES technology were merged into the final successful solution. Thus hypothesis H7: had been confirmed.

The traditional ES paradigm as represented in the literature was not replicated in the CAASS system, yet the scheduler's expertise was present in the "expert tools". The traditional DSS paradigm was expanded by the use of the "expert tools", to create a scheduler-driven system that was at least 60 times more powerful than the Case I DSS. This development required an elapsed time of 24 months.

The success of Case III, was attributed, in part, to the combination of continuous participation by a Vice President of Manufacturing who was an experienced scheduler, and a strong development team, including a knowledge programmer and myself as the system architect and knowledge engineer. The development environment was exceptional, and the financial resources were available.

In the period from 1984 to 1990, I had accumulated knowledge from several schedulers and manufacturing managers, as well as my own knowledge as a developer, trainer and sometime scheduler. From an ES viewpoint, based on this background and success it could be said that I had become an expert in developing GMI scheduling systems. Believing that the goal of capturing and recording this knowledge for future schedulers, management and developers was worthy, I tested the ES paradigm again by attempting to record my accumulated scheduling knowledge in the form of knowledge categories and scenarios. These techniques had independently been used in other ES domains(Vitalari 1985, Schvaneveldt 1985). As a result of applying these techniques and the subsequent analysis, I was able to develop theoretical foundations for the future versions of CAASS-like systems.

Combining the knowledge of the Cases, and the theoretical foundations established from the knowledge categories and scenarios, I again applied the ES paradigm in the evolutionary design of a scheduling system architecture, for future systems. The results were surprising to me. The resulting architecture presented a blueprint for the development of expert systems and ES development environments for many years to come.

This detailed study of scheduling knowledge following the three cases was undertaken as another test of the DSS/ES Hypothesis, H7. Rather then resulting in usable and useful scheduling systems, this analysis resulted in theoretical foundations for future scheduling system developments. These results suggest further positive evidence that the application of the DSS/ES paradigm leads to successful scheduling solutions.

10.3 CONTRIBUTIONS TO KNOWLEDGE

This question, I have interpreted to encompass the requirements that:

> the research focus must be non-trivial, the research study must be focused, original, unique, and substantial, and the results must be new and of value to the intended audiences.

In addition to the general conclusion stated in the beginning of this chapter, I believe the most significant, specific contributions to knowledge resulting from this research are:

1. The identification of the success factors that are essential in the application of DSS and ES technologies to the GMI scheduling problem; namely;
   "that macro and micro organizational factors must create

an environment for the subsequent successful implementation of components of DSS and ES technology to the GMI scheduling problem.

The success factors and their relationships are:

1. **Consistency of management involvement,**

   is essential to achieve:

2. **Minimum project duration of 24 months,**
3. **Organization of the scheduling function, and**
4. **Continuity of the key players,**

   while,

5. **The Scheduler and his organizational prominence and technical skills,**

   and

6. **The small but capable development team,**

   employ the methodology of

7. **Prototyping of the scheduling system,**

   to develop

8. **The scheduling model and its DSS and ES system representations, based on the guidelines of Chapters 8, 9 and Appendix E."**

2. The development of the CAASS system in Case III is a direct result of this study. This system has been recognized by international GMI management, schedulers, consultants, system developers, and researchers as a world class accomplishment. The specific achievements of this project include:

   1. The design and implementation of a new level of man/machine interface incorporating:

      - graphical representation of a complex numerical scheduling problem including resource demands, capacity and time constraints, calendars, and performance measures,

- graphical, mouse-initiated, scheduler tools designed solely to increase the productivity of the scheduler,

2. The replication of the scheduler's expertise into powerful "expert tools", to increase the scheduler's productivity by a factor of 60 times over spreadsheet systems.
3. The creation of a "scheduling workstation" to address the special needs of GMI schedulers.

3. The capture, documentation and analysis of GMI scheduling knowledge, in a form that can be augmented and utilized by future system architects to design and build their own interpretations of the scheduler's knowledge and system requirements.

4. The specification of expert scheduling system guidelines(Chapter 8, Appendix E) for use by management and scheduling system developers.

5. The design and documentation of a Generalized Three Tier Expert Scheduling System Architecture (Chapter 9) as a blueprint for developers of system development environments to facilitate the future development of scheduling systems.

As a result of these accomplishments, and with reference to my understanding of the intent of knowledge contributions, I believe this research has contributed to knowledge accordingly:

Research Focus: (must be non-trivial)

Clearly, the GMI scheduling problem, like all serious scheduling problems is not trivial.(Fox 1983, 1986, Sen, Tapen & Gupta 1983, Nassr 1985, Kusiak 1985). While the study of the DSS field has many excellent works, the general ES field is emerging, and the area of expert scheduling systems(ESS) is embryonic. Thus the study of the interfacing of the DSS and ESS fields as applied to this GMI problem is worthy.

Research Study: (focused, original, unique, and substantial)

Although this research study began and ended highly focused on the application of DSS/ES technologies to the GMI scheduling problem, in honesty, I fully admit that I lost my way among many interesting literary tangents. I rediscovered latent interests in Operations Research, Simulation, Decision Analysis, Japanese Manufacturing Techniques, and a host of other topics that I look forward to integrating with this research in the future. I was guided back to the original focus by the invitation to present to the 1990 Conference on Expert Systems in Production and Operations Management(Sawatzky & Peterson 1990). My advisor, R. Green Ph.D, and Viva committee, D. Sims Ph.D, and J. Bryant Ph.D helped me back to the original goal. My study of Hillway(1964) and Dawe(1978), and several Bath Ph.D graduates, assisted me greatly in my research into research. By employing the traditional research model of: purpose, hypothesis, methodology, observations, and conclusions(Hillway

1964), I was able to focus on the vision of this study.

Is this study original and unique? Although Fox(1986) and Nassr(1985) have reported expert scheduling systems, neither are in the GMI. Neither they nor others have reported a study methodology of a three case comparison of the application of DSS and ES technologies, nor the use of ES knowledge categories and scenarios to record and analyze scheduling knowledge. Thus I believe the study is original and unique.

Is the study substantial in effort, content, and quality of research? The magnitude of six years of study and effort, and the content and quality of the research, while not perfect, I believe to be within the flexible bounds of case study traditions. Bennett(1986) suggests such flexibility:

> "A key point to note about such studies(case Studies) is that they do not attempt rigorous control. This is both a strength and weakness" (Bennett 1986).

While the methodology lacks the rigour of empirical study, it is within Bennett(1986)'s scope of the achievement of practicable improvements, and the multiple objectives of research, consultancy and management training.

The Results:(new and of value to the intended audiences)

The intended audiences for this work are primarily GMI management, schedulers, system developers and researchers. Secondary audiences include general scheduling practitioners and researchers, in the fields of DSS and ES. In the primary audience, management and schedulers have and will find practical guidance in organizing and conducting scheduling system projects from the discussions of the cases to the specific conclusions of Chapter 8 and Appendix E. System developers will benefit from the specific design methodology and representations described in detail for each of the cases, in chapter 8 and 9, and Appendix E. Those interested in the general field of scheduling, including the practitioners, management, developers and researchers, may transfer many of the organizational, management, and development guidelines to their application. Scheduling systems researchers may compare their findings with those of this study.

10.4 METHODOLOGY ASSESSMENT

My research into research led me to attempt a methodology based on the scientific method, using the organization of: purpose, hypothesis, methodology, observations, and, conclusions(Hillway 1964). I concluded that this format would assist me in maintaining a clear focus on what I was studying and why.

The statement of my purpose and hypothesis evolved out of many versions. I briefly considered whether this was a study of DSS and ES development within the GMI , but easily choose the purpose of advancing the solution of GMI scheduling systems through the use of DSS/ES technologies The hypotheses and their confirmation thus became the testing of whether DSS, ES and merged DSS/ES technologies resulted in usable and useful GMI scheduling systems.

Determining a methodology to present the GMI scheduling problem, the DSS and ES literature, and test the hypotheses required considerable reflection and evolution. The description of the GMI scheduling problem(Chapter 3) was written with the purpose of showing that the problem was non-trivial and common among similar companies. Thus I compared the operations of six GMI companies to validate the significance of the problem and its breadth in the industry. As a framework for the analysis of the scheduling system I followed the traditional Production Operations Management view of the sub-tasks of scheduling. This analysis served well as an outline to measure, identify and compare the functions of each Case's system.

The succinct presentation of the DSS and ES literature proved a worthy challenge, that led to the formulation of the Case Description Outline(CDO) as a suitable instrument to identify what type of system each case was, how well it matched the DSS, or ES paradigm, and whether the case was successful. The lengthy effort expended in the development of the CDO facilitated the case analyses.

The methodology for testing the hypotheses began by considering how such hypotheses would be tested in a perfect laboratory, and then determining how to focus my analysis of available data into the hypotheses testing. The two methodologies had many similarities. Although many of the Bath Ph.D studies focused on single cases, the value of each of the three cases was too significant to omit any one.

Once the methodology was complete, the observations and conclusions were sequential and straightforward. The development of secondary and subsequent theoretical conclusions evolved as the foundation of the cases and the schedulers' knowledge grew with each small observation and conclusion leading to new realizations. I liken this research process to a long, uphill, unmapped journey that eventually leads to a distant summit. As the summit is scaled, it is not until the last few steps that the promise land on the other side becomes clearer with each closing step.

My role as researcher was an evolutionary transformation. I began as a curious consultant searching for a solution. I quickly came to appreciate the scholarly works of the previous authors of the many dissertations that I studied, and then had the personal satisfaction from studying several authors in specific topics related to DSS, ES, and many other sub-topics. This satisfaction was complete when my reflections on the literature combined with my own case conclusions to yield new thoughts that merged into concepts and finally theoretical propositions.

Although it now seems obvious, I have concluded that research requires lengthy elapsed time, persistence, patience, periodic contact with other researchers, a general focus, but above all, the time and environment to reflect upon the accumulated facts, information, knowledge, and readings. For me, this reflection was an evolving generation of new versions of each segment of this thesis. I spent uncountable hours and days generating, testing, and revising each version of the hypotheses, the methodology, the CDO, each case, each finding, and each theoretical proposition.

I played a major role as participant, and change agent(Brewer 1981) in the three cases. While it is possible to reflect upon the occurrences during such detailed involvement, I believe it is more important to thoroughly document these events for subsequent detailed scrutiny. Only after my daily involvement ceased was I able to view these cases, and my role, more objectively, and isolate important trends, and cause-effect relationships.

10.5 FUTURE RESEARCH DIRECTIONS

I believe the emergence of a new application of a new technology to a very difficult problem provides the potential for unbounded research. At the same time, with so few working expert scheduling systems or development projects underway, knowing what questions to ask is a challenge. This study, was a journey to find a solution, based on DSS and ES technologies. Another researcher, or future researchers could approach the journey with a view of studying a different technology or combination of technologies. Candidate technologies that I considered include neural networks, graphical simulation, mathematical analysis, mathematical programming, and enhanced or intelligent MRP systems, to name a few.

While I had the opportunity to study three cases, a more detailed study of one case could identify more specific findings of the detailed workings of the scheduling function within the organization. In my first version of the thesis I took such a detailed look at Case I, and found that Sims'(1978) work on problems could be applied to the vast array of scheduling related problems.

In this earlier draft I became very interested in the relationship between decision making and expertise. While this thesis considered this area briefly(Chapter 8), I believe it can be studied as to its deeper relevance to many types of system applications. Another area related to decision making and expertise is the cognitive profile of the decision maker or expert. From my observation of schedulers, some appear to be visual thinkers and respond and perform better to pictures, while others are verbal, etc. This consideration has implications for the design of scheduling systems where the final performance of the user may be enhanced by the matching of design representations to the scheduler's cognitive profile.

This study touched briefly upon the aspect of transferring one expert's system to a new expert, as in Case III, when the initial expert resigned and was replaced. Fortunately the replacement liked the system and became an excellent user. Why that happened, how to facilitate it happening, and the system implications are questions that require study.

The specific parts of this study that dealt with the knowledge of a scheduler need to be reassessed in a larger sample, with more formal study methodology and analysis. I believe this study is valuable for its early work, but future research could also examine the interpretation of the scheduling knowledge into other, more refined system requirements.

This study proposed the existence of many theoretical scheduling system precepts. From detailed representations and methodology approaches to long term system architectures, these propositions require more evaluation, refinement and practice.

From an ES methodology viewpoint, the cause-effect relationships that exist in the transition from a prototype project to a "delivery system" project require further study. In Case III, this transition resulted from a combination of the achievement of a measure of conceptual success, definition of enhancement requirements; partially defined in terms of prototype limitations, and technical limitations in the prototyping environment.

10.6 AUTHOR'S ASSESSMENT

This research has been a rewarding undertaking for me. The challenge and the goal of finding and developing successful scheduling solutions is a worthy objective. I am satisfied that the problem was worth spending over six years of my life to advance this area of knowledge.

I believe the degree of accomplishment will become more evident in the future. Yet even today, the practical benefits to the Case I and Case III companies are recognised. The recognition of the prototype research in the 1990 Conference on Expert Systems in Production and Operations Management(Sawatzky & Peterson 1990), has afforded me greater satisfaction. I believe that the greatest value of this research has yet to be realized, and will come in the future from the theoretical design guidelines that have evolved out of this work. Although I have reserved access to this thesis for several years, it is my intent to publish specific findings without reference to the companies involved. I am obligated to the GMI to assist companies searching for scheduling system solutions and intend to fulfil this obligation by publishing the guidelines derived in this research.

While I feel great satisfaction with the worthiness, substance and value of this research, the task of describing it in this dissertation has concerned me greatly. Balancing the criteria of length, and compactness, with clarity and completeness, remains a highly subjective assessment. If I have erred in this balance I hope that it is on the side of completeness for the sake of future readers.

APPENDIX A1
CASE DESCRIPTION OUTLINE(CDO)

The choice of specific characteristics to study in each case is vast. From a consideration of hundreds of case descriptors that previous researchers have used, an outline has been defined to identify the relevant dependent and independent variables.

From a research perspective the independent variables are:

1. The Company Environment(The Setting), prior to and during each project, as suggested by several authors.(Gibson and Nolan(1974), Huff and Munro(1985), King and Kraemer(1984), Ein-Dor and Segev(1978)).

2. The Design Process, as defined by the project methodologies.(Alter(1980), Montazemi(1986),Bailey and Pearson(1983), Raymond(1985)).

3. The Design Representation, as embodied in the resulting systems.(Alter(1980), Montazemi(1986),Bailey and Pearson(1983), Raymond(1985), Martin(1984)).

The dependent variable studied in this research is:

1. The Performance of the resulting systems in the form of success indicators suggested by Montazemi(1986), Bennet(19..), Martin(1984), Lucas(1975), Clowes(1979), and Vose(1990).

Classifications

The detailed classifications used to describe the three cases were derived from the literature review of DSS, Expert Systems and Expert Scheduling researchers and practitioners. The classifications are not intended to be exhaustive, but were selected to focus on the measures appropriate to test the main study hypothesis, and to facilitate description of observations not reported upon previously.

A section of the COD is directed to the identification of the concepts represented in the scheduling model concepts. These were derived from Chapter 3 and from the relevant concepts in the fields of Production/Operations Management, Operations Research, and Decision Analysis.

The reader is asked to refer to Appendix B1 for the detailed classifications so derived. Rather then repeat several pages of the CDO without a sample of the type of entries, I believe it is more meaningful to see the CDO in an actual Case.

APPENDIX A2

SECONDARY CASE COMPARISON

Comparison of Scheduling Systems
using Comparison criteria developed by
Harmon & King(1985) and Chryssolouris et al (1986)

System:	CASE I	CASE II	CASE III
Developer:	JP/Sched	JP	JP/VP-M
Purpose:(Domain) Area, Application Reason for building system	Plant Loading Desperation	Dept Sched Uncertainty	Plant load'g Opportun'y
Task: system is to accomplish	Schedule Prod.	Sched Fabrics	Batching & Sched Cuts
Input: data needed, method of acquiring	Aggregate Sales,SAMS Capacity	Aggr sales, B. Mat. SAMS Capacity	Cust. Orders SAMS Capacity
Output: results produced by system	Plant Loading	Cut Load'g Fab.Reqts	Cut Plan, Plant Load
Architecture: conceptual model ---	Model details as per Chryossolouris.--- et al.(1987)		
-Production Tasks	Total units/ style	Total units/ style	Customer order
-Production Resources	Sewing Lines	Depts	Depts or lines
-Work unit	SAM	SAM	SAM
-Multiple Levels	Yes	No	Yes
-Multiple depts	Combined	4	Combined
-Temporal unit	Week	Week	Minute
Planning Horizon			
-Maximum	16 weeks	42 weeks	52 weeks
-Minimum	16 weeks	16 weeks	1 day
No. of views	1	1	4

APPENDIX A2 continued

Tools: development & implemented	Lotus	Lotus	ART, Lisp Pascal
Results:			
-Performance,	Very good	Poor	Very good
-Years in use	5 years	5 months	2.5 years
-Status	Enhanced	Not used	Main tool
-Evaluation	good	Not used	very good

APPENDIX B1
CASE I DESCRIPTION

Classifications

The detailed classifications used to describe the three cases were derived from the literature review of DSS, Expert Systems and Expert Scheduling researchers and practitioners. The classifications are not intended to be exhaustive, but were selected to focus on the measures appropriate to test the main study hypothesis, and to facilitate description of observations not reported upon previously.

A section of the COD is directed to the identification of the concepts represented in the Scheduling Model. These were derived from Chapter 3 and from the relevant concepts in the fields of Production/Operations Management, Operations Research, and Decision Analysis. A final section on classification of Expert Systems is taken from Harmon & King (1985).

I. CASE SETTING:

The Setting:	Case I Description
Period:	Aug 1984-June 1987
Company:	Case I
Organizational situation.	
1. Co. strength	
1. Size	$80 millionUSD sales
2. Staff	600
3. Profitability	moderate
2. Management strength	
1. Organization	
-Senior Level	Chairman
-Second Level	President, 3 V. Presidents
-Third Level	Dept Directors & Mngrs
-Fourth Level	Supervisors
2. Strategic Planning, Control and Review.	3 formal Planning/Review(P/R) sessions per year(5 days long)
3. Tactical Planning, execution and control systems.	Carried out in 3 P/R sessions & managed by Level 2 executives
4. Operational plans & control systems.	Weekly Mngt Committee meetings of level 2 & 3's

II. PRODUCTION CHARACTERISTICS:

1.	TYPE:	
	a. MAKE-TO-ORDER,	Yes
	b. MAKE-FOR-STOCK,	Some
	c. JOB SHOP.	No
2.	Products:(Style types):	Sportswear, (300/yr)
3.	# of Plants:	8
4.	# of Sewing Lines:	12
5.	# of Factory Workers:	600
6.	Product Seasonality:	Yes
7.	Product Fashion Cycle:	3
8.	# of Product Lines/Season:	5
9.	# of Styles per Season:	100
10.	Co-ordinated groupings of styles:	15/yr

III PRODUCTION ORGANIZATION ASSESSMENT:

1.	Organizational Structure:	President responsible, several level 3's responsible for functional depts, and plants.
2.	Scheduling Organization	Formal 2 man dept at 4th level, reporting to Dir of Operations.
3.	Strategic, Tactical, Operational management styles	Seasonal Plan for all depts, plan monitored very closely by a Product Development committee
4.	Management Policies for:	
	Planning:	Formal
	Monitoring:	Seasonal Plan
	Control:	Product Devel. Committee Wkly Mngt Mtgs
	Formality of Policies, Programs, Procedures	Formal
5.	Scheduling function viewed as	Strategic-Customer Service, Tactical- Seasonal Plans Operational-Load Plants
6.	Project viewed as	Strategic

IV PROJECT INITIATION

Problem or opportunity	Problem, Issue Driven
Situation importance	
- Urgency	Critical-Chairman demanded resolution, prior schedulers transferred
- Cost/Value	$50,000+/season
Identification of the need.	
1. Need identified by whom and how?	Chairman
Initiated by whom and how?	
1. Approach initiated by:	Chairman
2. Key Players (degree of support) 1-High, 2-Med., 3-Low	Chairman(1) President(1) Level 3 mngrs(2) Consultant(1) New Schedulers(1)

V. THE DESIGN PROCESS

1. Project Organization and Goals
   Assign Team of: Dir Manuf, Scheduler, Consultant
   Goals: Must solve scheduling problem.

2. Project Staffing — Team with access to others as needed.

Key Player:	Scheduler	Consultant
Influence/Profile	High	High
Ability:	Proven	Proven
GMI Sched Experience:	Direct	None
Enthusiasm:	Contagious	Dedicated

Development Team:-		
Snr. Analyst:	Consultant	
Prog/Analyst		
Systems Ability:	Proven	Proven
GMI Sched Experience:	None	None

3. Project Methodology — Support Scheduler in prototyping of scheduling system.

4. System Implementation — Scheduler began using system within 2 weeks, development continued for 24 months.

MANAGEMENT INVOLVEMENT	
- Motivation	Very high priority
- Quantity (No.)	8 personnel directly involved .
- Quality (Levels)	Chairman: (1hr/mo) Pres (4 hr/mo) Dir Manuf(4 hr/wk) Dir Operns(4hr/wk) Schedulers(50hr/wk) Consultants(5-40hr/wk) Level-4's(20hr/wk)
Solution initiated by:	Team
Project Objectives:	
Key Emphasis - User Involvement	
Support a key decision maker	Yes
Replicate an Expert	
Solve a Problem	Yes
Build a Model/System	Yes
Project Orientation:	
MIS:Provide Information	No
DSS:Support DM processes	Yes,
ES :Replicate expert	No
Project Resources:	
Scheduling staff	
-Quantity	Scheduler +
Asstnt -Experience	5 yrs
-Quality	Mngt Potential
-Motivation	Self-Preservation
Developers:	
-Quantity	2
-Quality	Reasonable
-Motivation	High
-Experience with Co.	5 yrs as
Consultants	
Development Equipment	8086 PC
-Quantity	2
-Quality	Good
Operational Equipment	IBM PC-AT
-Quantity	2
-Quality	Very good
Development Environment	
-Quantity	Scheduling Office
-Quality	V.Good

Phases	Multiple: Prototyping	
	Budget	Actual
Time Plan:	urgent	24 months
Cost:	open	$50,000+
Resources:	Plan	Actual
Development Staff:	2	2
User Staff:	5	8
Equipment:	PC-8086	2 PC-AT
System Software:	DOS	DOS
Application Software:	Lotus 1-2-3	same
Packages:	none	none
Tools:	none	Lotus macros & graphics

Project Methodology:

Prototyping — Support Scheduler's Models

Evolutionary — Original plan was to a develop prototype on PC then port to IBM/38. IBM/38 version was not technically feasible.

Middle-out

Life Cycle

Agreement with Keen and Gambo(1983) Methodology:

1. Design the dialogue first.
   a. Define what the user says and sees
      Yes

   b. Define the representation of data
      Yes

   c. Adopt a system model which matches the user's conceptional model. Yes

2. Identify the user's special purpose verbs.
   Yes

3. Identify generic verbs relevant to this DSS.
   Yes

4. Translate the verbs into commands, and vice versa.
   Yes

5. Check out public libraries for off the shelf routines.
   No-prior study determined no GMI scheduling packages existed.

6. Set priorities for implementing commands for version zero.
   Yes

7. Support first, extend later. Yes

8. Deliver version zero quickly and cheaply.
   Yes

   a. Evolve a complex DSS out of a simple version zero
      Yes

   b. Version zero is intended to establish value and to sell itself. Yes

9. Pick a good user who: Yes

   a. Has substantial knowledge of the task,
      Yes

   b. Has intellectual drive and curiosity,
      Yes

   c. Will take the initiative in testing and in evolving version zero, and Yes

   d. Enjoys being an innovator. Yes

10. Recognize data management, rather than commands, as a main constraint. Yes

11. Remember that Brooks is right - programming is 10% of the effort. No

12. Know your user at all times. Yes

13. Rule 11 may be restated in several ways:
    a. Programming is 10% of the effort
       No

    b. If you want to build a product that will stand by itself, recognize the time and effort needed
       Yes

    c. Version zero can be built in weeks."
       Yes

Acceptance Criteria: Scheduler performance

Project Completion Process/Procedure/Cut-off
None

Post Implementation Review:
3 times per year
2 Separate reviews

VI THE DESIGN REPRESENTATIONS

Scheduling Model represented as:	Spreadsheet model of sales orders, weekly plant and contractor capacity
Systems Model	2 integrated Lotus spreadsheets
User Interface and interaction	Several Lotus macros
Systems Integration	No integration with MIS MIS reports used for inputs
Management level supported by system	
Operational	Yes
Tactical	Yes
Strategic	Yes
Degree and characteristics:	
Tools	Lotus macros
Status Review	Lotus
What-If	Yes
DBMS Representations:	
Structures	Spreadsheets
Relationships	2-levels of integrated spreadsheets
Knowledge Representations	
Conceptual	Implicit
LISP	None
Prolog	None

Main system model features:

-menu for entry/display/alter — Yes

-menu of items for controllable and non-controllable variables. — No

-illustration of non-controllable variables over a time period. — Yes

-pair wise comparison of alternatives — No

-a working set and a reference set interchangeable and re-accessible. — Yes

-function menu by phase of the decision process — No

-shallow hierarchy of functions — Yes

User Interface	
-simple,	No
-responsive,	
-user interaction	Yes
-turnaround time	5-15 min.
-user-controlled,	
-menus	Yes
-mouse commands	No
-object icons	No
-help command	Yes-limited
-training examples	Yes
-combined operations	Yes
-user construction of combined operations	
- changing defaults	No
-user specification of graphs/reports	Limited options
-flexible,	Yes
-stable,	Yes
-protective,	Yes
-self documenting	Yes
-reliable	Yes
-input forms/output forms	Yes
-checkmark selections	No
Standard Interface:	
Lotus	Yes
DEC Terminal Text Menus	
Monochrome, Colour	Monochrome
Keyboard, Mouse	Keyboard
Menu	Plants
Macintosh interface	
Allegro Lisp	
Prolog	
Custom designed	
Workstation	IBM PC-AT
Connectivity:	None
User Support Acceptance	Scheduler-yes

-identification of several decision alternatives,
Yes

-the exploration of these alternatives,
Yes

-the identification of uncertain elements or developments,
Yes

-the assembling of information from a wide variety of sources and decision aids,
No

-processing the appropriate models to execute these with the different alternatives and scenarios considered

No

-to present in a user friendly reporting method the results of these different analyses.

Yes graphs showing performance

VII THE RESULTS

1. Status Indicators

1.	Transition Period	1-24 months
2.	Time to Full/Exclusive Use	6-12 months
3.	Status from start:	
	6 months.	Scheduler using system-evolution continuing
	12 months	"" "" ""
	24 months	"" "" ""
	36 months	"" "" ""

2. Performance Indicators

1.	Degree of Use	Full time
2.	Reliance on System	100%
	1. Believers	All levels of mngt
	2. Non-Believers	- some want enhancements
3.	Accuracy of System	
	1. Problem Predictive ability	Proven
	2. Solution Analysis ability	Proven
	3. Solution Choice ability	Proven

Objectives/Degree of Achievement	High
Documentation	Minimal since schedulers know system very well.
Concepts Designed	Multiple plant loading Weekly reporting 6,12 & 18 mo planning Material deliveries co-ordinated.

Value Indicators

1. Customer order delivery improvements	V.Good
2. Management planning/control improvements	V.Good
3. Catalyst for other improvements.	Many
4. External Recognition.	From contractors

Enhancement/Evolution of Systems

1. Strategic	Yes
2. Tactical	Yes
3. Operational	Yes

Limitations Associated with the System.

1. Organizational Problems	Solved over 12 months
2. Technological Limitations	No integration with MIS
3. Functional Limitations	Lotus competence req'd
4. Other Limitations.	Model complexity and dynamic use made enhancement implementation very difficult.

Management Acceptance	Excellent

VIII. COMPARISON OF CONCLUSIONS:

A. Keen and Gambo(1983)

1. The importance of prototyping as a means of definition of requirements, Yes

2. The importance of user learning in terms of the evolution of the system, Yes

3. The use of "adaptive design" involving close liaison between the user and the designer, Yes

4. The importance of the user system interface, Yes

5. The importance of picking a good user, Yes

6. A development cycle with stimulus coming both from the system and from the users for continued evolution, Yes

7. The importance of using a development tool or language which can be modified quickly. Yes

8. The importance of specific user verbs and their correspondence to system commands. Yes

B. Moore and Chang(1983)

1. The migration of both the system design and the problem understanding over time. Yes

2. Expansion of situation capabilities. Yes

3. The evolution from initial "soft" capabilities into more firmly designed hard capabilities. Yes

4. The use of the system to mould and shape the user's decision making processes rather than copying current processes. Yes

C. Gorry and Krumland(1983)

1. Problem evolves from unstructured to structured. Yes

D. Altar(1980) DSS Types

1. File drawer systems,
2. Data analysis systems,
3. Analysis information systems,
4. Accounting models,
5. Representational models, including simulation models, Yes
6. Optimization models, and
7. Suggestion models. Yes

E. Stabell(1983)

1. **Decision channelling through the** interface architecture that serves to both support existing decision processes and to shift future processes into the more extensive and powerful use of the tools. To accomplish these, suggested features include:
   1. presentation form for logical data structures,
      Yes
   2. system defaults, Yes
   3. differential ease of transition between different system functions, and Yes
   4. the structure of memory aids.
      Yes

2. Focus attention on the nature of the decision problem by differentiating between the control variables which define decision alternatives, non-controllable variables that the decision maker cannot control but that affect the desired decision outcomes or decision criteria.
   Yes

3. Facilitate the evaluation of alternatives by providing user controlled report or scanning capabilities to facilitate comparison on the basis of multiple decision criteria.
   Yes, but regeneration slow(5-15 min.)

4. Extend the planning horizon giving default definitions of variables as if they were time dependent to remind the decision maker of possible changes.
   Yes

5. Support uncertainty exploration by allowing the simulation of consequences of differences in cause/effect and states of the environment. Yes, but regeneration slow.

6. Facilitate the integration of the user's subjective estimates allowing him to modify a private copy of data inputs as well as other readily available and objective computer based data.
   Yes

7. Facilitate learning by providing functions for recording and revisiting key decision assumptions. In this respect the results of certain decisions should be monitored and where possible indications reentered to indicate the quality of the decision based on the use of the DSS with a given set of variables and parameters.
   Yes

F. Carlson(1983)

1. DSS should provide familiar representations, (eg. charts and graphs) Yes

2. DSS should support Intelligence, Yes
   Design, Yes
   Choice. Yes

3. DSS should provide memory aids Yes

4. DSS should help decision makers work in their own idiosyncratic ways. Yes

5. DSS should provide control aids which help decision makers exercise direct, personal control. Yes

IX SCHEDULING MODEL REPRESENTATION
(derived from Chapter 3)
Identification of Model features, scope, and depth.

A. Basic Scheduling Components(Wild 1985,Stevenson 1982, Buffa 1968, Lockyer 1985)

1. Sales Forecasting
   1. Quantitative methods — None
      1. Historical Smoothing models
      2. Predictive models
   2. Qualitative Methods — None
      1. Delphi
      2. Consensus
   3. Planning Horizon Time
      1. Year
      2. Quarter — 2-3 at once
      3. Month
      4. Week — lowest unit of time
      5. Day
      6. Hour
      7. Minute

2. Capacity Planning
   1. Management of Demand Uncertainty for:
      1. No. of Orders — No
      2. Work per Order — Yes, in total by Delivery date

   2. Stages of Capacity Planning
      1. Average Levels Req'd — Yes
      2. Variations to Average — Yes

   3. Capacity Management Strategies
      1. Adjustment of Capacity — Yes
         1. Capacity Increases — Yes
         a. subcontract — Yes
         b. reduce material content — No
         c. substitute available material — No
         d. increase supply schedules — Yes
         e. transfer from other jobs — No
         f. defer maintenance — Yes
         h. increase work force size — Yes
         i. increase working hours — Yes

         2. Capacity Reductions — Yes
         a. retrieve work from subcontractors — Yes
         b. reduce supply schedules — Yes
         c. transfer materials to other jobs — Yes
         d. advance maintenance schedules — Yes
         e. reduce work force size — Yes
         f. reduce working hours — Yes

2. Eliminate need for Adjustment — No
   1. Maintain excess capacity — No
   2. Accept loss of orders — No
   3. Deliver late — No
   4. Create inventories — No

3. Material Acquisition and Control
   1. Material Requirements Planning — No - delivery only

4. Aggregate Planning and Scheduling
   1. Multiple channels(plants) — Yes
   2. Multiple products-Manufacturing req'ts planning — Yes
   3. Multiple Sales Forecasts — Yes
   4. Multiple Plans — Yes
   5. Activity Scheduling — Yes

B. Integration of Operations Research Concepts:
   1. Mathematical models
      a. Job Shop — No
      b. Flow Shop — No

   2. Performance Measures — Non-Optimum
      a. Minimize Tardiness — No
      b. Minimize no. of tardy jobs — No
      c. Minimize ave. tardiness — Yes
      d. Maximize utilization — Yes
      e. Minimize Work-in-process — Yes
      e.

   3. Multi Criteria Decision Making
      a. Option Evaluation — Yes
      b. Weighted Criteria — No

   4. Simulation
      a. Control Strategy Evaluation — No
      b. Model of Physical plant — Yes
      c. Queue Representations — Yes

APPENDIX B2
CASE II DESCRIPTION

Classifications

The detailed classifications used to describe the three cases were derived from the literature review of DSS, Expert Systems and Expert Scheduling researchers and practitioners. The classifications are not intended to be exhaustive, but were selected to focus on the measures appropriate to test the main study hypothesis, and to facilitate description of observations not reported upon previously.

A section of the COD is directed to the identification of the concepts represented in the scheduling model concepts. These were derived from Chapter 3 and from the relevant concepts in the fields of Production/Operations Management, Operations Research, and Decision Analysis.

I. CASE SETTING:

The Setting:	<u>Case II Description</u>
Period:	May 1988-Feb 1989
Company:	Case II
Organizational situation.	
1. Co. strength	
1. Size	$40 millionUSD sales
2. Staff	300
3. Profitability	moderate
2. Management strength	
1. Organization	
2. Strategic Planning, Control and Review.	Informal
3. Tactical Planning, execution and control systems.	Informal
4. Operational plans & control systems.	Informal
3. Manufacturing strength	
1. Organization	Key Plant Mngr
2. Scheduling function	Not isolated

II. PRODUCTION CHARACTERISTICS:

1.	TYPE:	
	a. MAKE-TO-ORDER,	Yes
	b. MAKE-FOR-STOCK,	No
	c. JOB SHOP.	No
2.	Products:(Style types):	Sportswear, Coats(100)
3.	# of Plants:	4
4.	# of Sewing Lines:	6
5.	# of Factory Workers:	300
6.	Product Seasonality:	Yes
7.	Product Fashion Cycle:	2
8.	# of Product Lines/Season:	5
9.	# of Styles per Season:	100
10.	Co-ordinated groupings of styles:	2

III PRODUCTION ORGANIZATION ASSESSMENT:

1.	Organizational Structure:	Dept head committee(4)
2.	Scheduling Organization:	None before project
3.	Strategic, Tactical, Operational management styles	Informal
4.	Management Policies for:	
	Planning:	Informal, Undisciplined
	Monitoring:	President's intervention
	Control:	President's intervention
	Formality of Policies, Programs, Procedures	Informal
5.	Scheduling function viewed as	Operational
6.	Project viewed as	Operational

IV PROJECT INITIATION

Problem or opportunity	Opportunity
Situation importance	
- Urgency	Not Critical, late deliveries were a re-occurring problem.
- Cost/Value	Not quantified

Identification of the need.

1. Need identified by whom and how? Consultant-1, Pres,GM

Initiated by whom and how?

1. Approach initiated by:	Consultant-1
2. Key Players (degree of support) 1-High, 2-Med., 3-Low	President(2) General Manager(2) Prod'n Managers(3) Consultant-2(1) New Scheduler(1)

V. THE DESIGN PROCESS

1. Project Organization and Goals — 1-Consultant Survey; 2-Develop System; 3-Scheduling Assistance

2. Project Staffing — Consultant-2 initially, Scheduler hired in 4 weeks

User Team:-		
Key Player:	Scheduler	Consult-2
Influence:	Unproven	Good Refer.
Ability:	Unproven	Proven
GMI Sched Experience:	Indirect	Direct

Development Team:-		
Snr. Analyst:	Consultant-2	Consult-1
Systems Ability:	Proven	Novice
GMI Sched Experience:	Direct	Indirect

3. Project Methodology — Adaptation and expansion of Case I models, followed by evolution with users.

4. System Implementation — 1 season parallel before new scheduler resigned

MANAGEMENT INVOLVEMENT	
- Motivation	Hopeful for solution
- Quantity (No.)	Pres, GM, 3 middle mngrs
- Quality (Levels)	Pres-1 hr/mo. GM- 1 hr/wk Middle mngrs-3 hrs/wk
Solution initiated by:	Consultant-1
Project Objectives:	
Key Emphasis - User Involvement	
Support a key decision maker	No
Replicate an Expert	No
Solve a Problem	Yes
Build a Model/System	Yes
Project Orientation:	
MIS:Provide Information	No
DSS:Support DM processes	Yes, no scheduler existed. 3 mid-mngrs did scheduling
ES :Replicate expert	No
Project Resources:	
Scheduling staff	
-Quantity	New employee
-Experience	None in GMI
-Quality	1
-Motivation	Hopeful
Developers:	
-Quantity	1
-Quality	Reasonable
-Motivation	High
-Experience with Co.	None
Development Equipment	8086 PC
-Quantity	2
-Quality	Poor
Operational Equipment	Compaq 80386-v,good
-Quantity	1
-Quality	Very good
Development Environment	
-Quantity	1 Office
-Quality	Poor

Phases	3-Survey, Devel, Assist	
Time Plan:	6 months	
Budget: and Actual Cost:	$15000	$13000
Resources:	Plan	Actual
Development Staff:	1	1
User Staff:	5	1
Equipment:	PC-8086, & PC 80386	
System Software:	DOS	
Application Software:	Lotus 1-2-3	
Packages:	none	
Tools:	none	

Project Methodology:
Prototyping
Evolutionary — Adapt Case I model
Middle-out
Life Cycle

Agreement with Keen and Gambo(1983) Methodology:

1. Design the dialogue first.
   a. Define what the user says and sees — No
   b. Define the representation of data — Yes
   c. Adopt a system model which matches the user's conceptional model. — Yes
2. Identify the user's special purpose verbs. — Yes
3. Identify generic verbs relevant to this DSS. — Yes
4. Translate the verbs into commands, and vice versa. — Some
5. Check out public libraries for off the shelf routines. — No-used Case I concepts
6. Set priorities for implementing commands for version zero. — Yes
7. Support first, extend later. — No
8. Deliver version zero quickly and cheaply. — Yes
   a. Evolve a complex DSS out of a simple version zero — Yes
   b. Version zero is intended to establish value and to sell itself. — Yes

9. Pick a good user who: No

   a. Has substantial knowledge of the task, No

   b. Has intellectual drive and curiosity, Yes

   c. Will take the initiative in testing and in evolving version zero, and No

   d. Enjoys being an innovator. No

10. Recognize data management, rather than commands, as a main constraint. Yes

11. Remember that Brooks is right - programming is 10% of the effort. No

12. Know your user at all times. No

13. Rule 11 may be restated in several ways:
   a. Programming is 10% of the effort No

   b. If you want to build a product that will stand by itself, recognize the time and effort needed No

   c. Version zero can be built in weeks." Yes

Acceptance Criteria:	Informal demonstration
Project Completion Process/Procedure/Cut-off	None
Post Implementation Review:	None

VI THE DESIGN REPRESENTATIONS

Scheduling Model represented as:	Spreadsheet model of sales orders, weekly capacity, department scheduling. fabric reqts
Systems Model	8 integrated Lotus spreadsheets
User Interface and interaction	Standard Lotus-no macros
Systems Integration	No integration with MIS

Management level supported by system

Operational	Yes
Tactical	No
Strategic	No

Degree and characteristics:

Tools	Simple Lotus
Status Review	Std Lotus
What-If	Yes

DBMS Representations:

Structures	Spreadsheets
Relationships	8 integrated

Knowledge Representations

Conceptual	Implicit
LISP	None
Prolog	None

Main system model features:

-menu for entry/display/alter	No
-menu of items for controllable and non-controllable variables.	No
-illustration of non-controllable variables over a time period.	Yes
-pair wise comparison of alternatives	No
-a working set and a reference set interchangeable and re-accessible.	Yes
-function menu by phase of the decision process	No
-shallow hierarchy of functions	Yes

User Interface	
-simple,	No
-responsive,	
-user interaction	Yes
-turnaround time	5-30 min.
-user-controlled,	
-menus	No
-mouse commands	No
-object icons	No
-help command	No
-training examples	Yes
-combined operations	No
-user construction of combined operations	
- changing defaults	No
-user specification of graphs/reports	No
-flexible,	Yes
-stable,	No
-protective,	No
-self documenting	Yes
-reliable	No
-input forms/output forms	Yes
-checkmark selections	No
Standard Interface:	
Lotus	Yes
DEC Terminal Text Menus	
Monochrome, Colour	Colour
Keyboard, Mouse	Keyboard
Menu	File list
Macintosh interface	
Allegro Lisp	
Prolog	
Custom designed	
Workstation	Compaq 80386
Connectivity:	None
User Support Acceptance	Scheduler-yes
-identification of several decision alternatives,	Yes
-the exploration of these alternatives,	Yes
-the identification of uncertain elements or developments,	Yes
-the assembling of information from a wide variety of sources and decision aids,	No
-processing the appropriate models to execute these with the different alternatives and scenarios considered	No

-to present in a user friendly reporting method the results of these different analyses.

No

I THE RESULTS

Status Indicators

1. Transition Period	5 months
2. Time to Full/Exclusive Use	Not achieved
3. Status from start:	
6 months.	New scheduler in training
12 months	Not used

Performance Indicators

1. Degree of Use	None
2. Reliance on System	None
1. Believers	Consultants
2. Non-Believers	Co. staff
3. Accuracy of System	
1. Problem Predictive ability	Unproven
2. Solution Analysis ability	Trial appeared good
3. Solution Choice ability	Trial appeared good

Objectives/Degree of Achievement	Not implemented
Documentation	None
Concepts Designed	Dept interrelation, Production Window, Material Req'ts.

Value Indicators

1. Customer order delivery improvements	None
2. Management planning/control improvements	None
3. Catalyst for other improvements.	None
4. External Recognition.	None

Enhancement/Evolution of Systems

1. Strategic	None
2. Tactical	None
3. Operational	None

Limitations Associated with the System.

1.	Organizational Problems	Scheduler staffing weak
2.	Technological Limitations	Schedule regeneration required 5-30 minutes to regenerate schedule.
3.	Functional Limitations	Lotus competence req'd
4.	Other Limitations.	Dedicated Scheduler req'd

Management Acceptance Unconfirmed

VIII. COMPARISON OF CONCLUSIONS:

A. Keen and Gambo(1983)

1. The importance of prototyping as a means of definition of requirements, Yes

2. The importance of user learning in terms of the evolution of the system, Unconfirmed

3. The use of "adaptive design" involving close liaison between the user and the designer, Unconfirmed

4. The importance of the user system interface, Yes

5. The importance of picking a good user, Unconfirmed

6. A development cycle with stimulus coming both from the system and from the users for continued evolution, Unconfirmed

7. The importance of using a development tool or language which can be modified quickly. Yes

8. The importance of specific user verbs and their correspondence to system commands. Yes

B. Moore and Chang(1983)

1. The migration of both the system design and the problem understanding over time. Yes

2. Expansion of situation capabilities. Yes

3. The evolution from initial "soft" capabilities into more firmly designed hard capabilities. Yes

The use of the system to mould and shape the user's decision making processes rather than copying current processes.
Yes

Gorry and Krumland(1983)
Problem evolves from unstructured to structured.
Yes

Altar(1980) DSS Types
1. File drawer systems,
2. Data analysis systems,
3. Analysis information systems,
4. Accounting models,
5. Representational models, including simulation models, Yes
6. Optimization models, and
7. Suggestion models. Yes

Stabell(1983)
Decision channelling through the interface architecture that serves to both support existing decision processes and to shift future processes into the more extensive and powerful use of the tools. To accomplish these, suggested features include:
1. presentation form for logical data structures,
Yes
2. system defaults, Yes
3. differential ease of transition between different system functions, and Yes
4. the structure of memory aids.
Yes

Focus attention on the nature of the decision problem by differentiating between the control variables which define decision alternatives, non-controllable variables that the decision maker cannot control but that affect the desired decision outcomes or decision criteria.
Yes

Facilitate the evaluation of alternatives by providing user controlled report or scanning capabilities to facilitate comparison on the basis of multiple decision criteria.
Yes, but regeneration very slow(5-30 min.)

Extend the planning horizon giving default definitions of variables as if they were time dependent to remind the decision maker of possible changes.
No

Support uncertainty exploration by allowing the simulation of consequences of differences in cause/effect and states of the environment. Yes, but regeneration very slow.

6. Facilitate the integration of the user's subjective estimates allowing him to modify a private copy of data inputs as well as other readily available and objective computer based data.

Yes

7. Facilitate learning by providing functions for recording and revisiting key decision assumptions. In this respect the results of certain decisions should be monitored and where possible indications reentered to indicate the quality of the decision based on the use of the DSS with a given set of variables and parameters.

Yes

F. Carlson(1983)

1. DSS should provide familiar representations, (eg. charts and graphs) Yes

2. DSS should support Intelligence, Yes
   Design, Yes
   Choice. Yes

3. DSS should provide memory aids Yes

4. DSS should help decision makers work in their own idiosyncratic ways. No

5. DSS should provide control aids which help decision makers exercise direct, personal control.

Yes

IX SCHEDULING MODEL REPRESENTATION

Identification of Model features, scope, and depth.

A. Basic Scheduling Components(Wild 1985, Stevenson 1982, Buffa 1968, Lockyer 1983)

```
1.   Sales Forecasting
     1.   Quantitative methods          None
          1.   Historical Smoothing models
          2.   Predictive models
     2.   Qualitative Methods           None
          1.   Delphi
          2.   Consensus
     3.   Planning Horizon Time
          1.   Year
          2.   Quarter                  2-3 at once
          3.   Month
          4.   Week                     lowest unit of time
          5.   Day
          6.   Hour
          7.   Minute

2.   Capacity Planning
     1.   Management of Demand Uncertainty for:
          1.   No. of Orders            No
          2.   Work per Order           Yes, in total by Delivery
                                        date

     2.   Stages of Capacity Planning
          1.   Average Levels Req'd     Yes
          2.   Variations to Average    Yes

     3.   Capacity Management Strategies
          1.   Adjustment of Capacity             Yes
               1.   Capacity Increases            Yes
               a.   subcontract                   Yes
               b.   reduce material content       No
               c.   substitute available material No
               d.   increase supply schedules     Yes
               e.   transfer from other jobs      No
               f.   defer maintenance             Yes
               h.   increase work force size      Yes
               i.   increase working hours        Yes

               2.   Capacity Reductions                     Yes
               a.   retrieve work from subcontractors       Yes
               b.   reduce supply schedules                 Yes
               c.   transfer materials to other jobs        Yes
               d.   advance maintenance schedules           Yes
               e.   reduce work force size                  Yes
               f.   reduce working hours                    Yes

          2.   Eliminate need for Adjustment      No
               1.   Maintain excess capacity      No
               2.   Accept loss of orders         No
               3.   Deliver late                  No
               4.   Create inventories            No
```

Material Acquisition and Control

1.	Material Requirements Planning	Yes

Aggregate Planning and Scheduling

1.	Multiple channels(plants)	Yes
2.	Multiple products-Manufacturing req'ts planning	Yes
3.	Multiple Sales Forecasts	Yes
4.	Multiple Plans	Yes
5.	Activity Scheduling	Yes

Integration of Operations Research Concepts:

1.	Mathematical models		
	a.	Job Shop	No
	b.	Flow Shop	No
2.	Performance Measures		Non-Optimum
	a.	Minimize Tardiness	Yes
	b.	Minimize no. of tardy jobs	Yes
	c.	Minimize ave. tardiness	Yes
	d.	Maximize utilization	Yes
	e.	Minimize Work-in-process	Yes
	e.		
3.	Multi Criteria Decision Making		
	a.	Option Evaluation	Yes
	b.	Weighted Criteria	No
4.	Simulation		
	a.	Control Strategy Evaluation	No
	b.	Model of Physical plant	Yes
	c.	Queue Representations	Yes

APPENDIX B3
CASE III DESCRIPTION

Classifications

The detailed classifications used to describe the three cases were derived from the literature review of DSS, Expert Systems and Expert Scheduling researchers and practitioners. The classifications are not intended to be exhaustive, but were selected to focus on the measures appropriate to test the main study hypothesis, and to facilitate description of observations not reported upon previously.

A section of the COD is directed to the identification of the concepts represented in the scheduling model concepts. These were derived from Chapter 3 and from the relevant concepts in the fields of Production/Operations Management, Operations Research, and Decision Analysis.

I. CASE SETTING:

The Setting:	<u>Case III Description</u>
Period:	Aug 1987-Dec 1990
Company:	Case III: Sterling Stall Group(SSG)
Organizational situation.	
1. Co. strength	
1. Size	$40millionUSD sales
2. Staff	300
3. Profitability	moderate
2. Management strength	
1. Organization	
-Senior Level	Chairman
-Second Level	President, 4 Vice Presidents
-Third Level	Dept Directors & Mngrs
-Fourth Level	Supervisors
2. Strategic Planning, Control and Review.	Carried out by Chairman and Vice President annually.
3. Tactical Planning, execution and control systems.	Carried out each season by Pres. and V.Pres's i.e. Level 2's
4. Operational plans & control systems.	Weekly Division mtgs of levels 2,3, and 4's

II. PRODUCTION CHARACTERISTICS:

1.	TYPE:	
	a. MAKE-TO-ORDER,	Yes
	b. MAKE-FOR-STOCK,	No
	c. JOB SHOP.	No
2.	Products:(Style types):	Sportswear, (200/yr)
3.	# of Plants:	4
4.	# of Sewing Lines:	6
5.	# of Factory Workers:	300
6.	Product Seasonality:	Yes
7.	Product Fashion Cycle:	2
8.	# of Product Lines/Season:	8
9.	# of Styles per Season:	100
10	Co-ordinated groupings of styles:	15/yr

III PRODUCTION ORGANIZATION ASSESSMENT:

1.	Organizational Structure:	Vice Pres. of Manufacturing responsible to President. Depts heads reported to V.Pres Manuf.
2.	Scheduling Organization	V.P Manuf. with a production supervisor-assistant.
3.	Strategic, Tactical, Operational	Weekly Divisional meetings monitored sales, fabric deliveries and production schedule very closely.
4.	Management Policies for:	
	Planning:	Simple seasonal plans
	Monitoring:	Weekly meetings, hands-on mngt by Pres. and V.Presidents.
	Control:	Pres., V.Pres's and Level 4's at Wkly Div. mtgs
	Formality of Policies, Programs, Procedures	Informal based on a very high level of competence by each key executive, and hands-on mngt by key exec's.
5.	Scheduling function viewed as	Strategic-Customer Service, Tactical- Seasonal Plans

Operational-Load Plants

6.	Project viewed as	Strategic

IV PROJECT INITIATION

Problem or opportunity	Opportunity
Situation importance - Urgency	Initiated by researcher with close friend V.P Manuf. of SSG. who was having problems managing schedules.
- Cost/Value	not assessed

Identification of the need.
1. Need identified by whom and how?
VP Manuf with researcher.

Initiated by whom and how?

1. Approach initiated by:	Researcher
2. Key Players (degree of support) 1-High, 2-Med., 3-Low	VP Manuf(1) VP Finance(2) Pres(2)

V. THE DESIGN PROCESS

1. Project Organization and Goals
   Assign Team of: VP Manuf, Researcher,NRC-K.E.
   Goals: Apply ES to GMI scheduling problem.

2. Project Staffing — Team with access to others as needed.

Key Player:	VPManuf.	Researcher
Influence/Profile	High	High
Ability:	Proven	Proven
GMI Sched Experience:	Direct	Case I & Ph.D study
Enthusiasm:	Consistent	Consistent
Development Team:-		
Snr. Analyst:	Researcher	NRC-K.E.
Systems Ability:	Proven	Some
GMI Sched Experience:	Case I & Ph.D study	None
Knowledge Eng. Experience	Studied only	Studied only

3. Project Methodology — Represent Vp Manuf scheduling expertise in prototyping of scheduling system.

4. System Implementation — First prototype in 5 months, last prototype after 16 months, first delivery system(CAASS) 20 months from start. CAASS now in use for 30 months(as of Sept 91).

MANAGEMENT INVOLVEMENT	
- Motivation	Hopeful
- Quantity (No.)	1-VP Manuf
- Quality (Levels)	VP Manuf.(3hr/wk)
Solution initiated by:	In SSG by VP Manuf.
Project Objectives:	
Key Emphasis - User Involvement:	
Support a key decision maker	Yes
Replicate an Expert	Yes
Solve a Problem	Yes
Build a Model/System	Yes
Project Orientation:	
MIS:Provide Information	No
DSS:Support DM processes	Yes,
ES :Replicate expert	Yes
Project Resources:	
Scheduling staff	
-Quantity	VP Manuf,
-Experience	20 yrs
-Quality(Poor, Good, V.Good, Excellent)	Excellent
-Motivation	Scheduling Performance & Co. Success.
Developers:	
-Quantity	2
-Quality	Very Good
-Motivation	High
-Experience with Co.	none
Development Equipment	DEC VAX, DEC PC, Symbolics AI-workstation, Macintosh II
-Quantity	unlimited
-Quality	Excellent
Operational Equipment	Mac IIc
-Quantity	1
-Quality	Very good
Development Environment	
-Quantity	Project office
-Quality	Excellent

Phase I	Prototype Budget	Actual
Time Plan:	24 mos	24 months
Cost:Prototype	$100,000	$140,000+equip

Resources:	Plan	Actual
Development Staff:	2	2
User Staff:	1	1
Equipment:	DEC VAX	VAX, Symbolics Mac II
System Software:	VAX	VAX, Symbolics, Mac II
Application Software:	ART	ART, Lisp, KEE, Allegro Lisp
Packages:	as above	as above
Tools:	as above	as above

Phase II	Delivery System	
	Budget	Actual
Time Plan:	6 mos	V1.0 6 mos V1.4 18 mos
Cost:V1.4 (excludes user time)	$50,000	$100,000

Resources:	Plan	Actual
Development Staff:	1.2	1.2
User Staff:	1	1
Equipment:	Mac II	Mac II
System Software:	Mac	Mac
Application Software:	Pascal	Pascal
Packages:	none	Communications
Tools:	none	none

Project Methodology:	
Knowledge Acquisition (Knowledge Elicitation)	Replicate Expert scheduler's structures and processes.
Prototyping	Automate structures and processes. Proof of concept.
Evolutionary	Enhance prototype, then develop delivery system.
Middle-out	
Life Cycle	

reement with Keen and Gambo(1983) Methodology:

Design the dialogue first.

a. Define what the user says and sees
Yes

b. Define the representation of data
Yes, with knowledge added

c. Adopt a system model which matches the user's conceptional model. Yes

Identify the user's special purpose verbs.
Yes

Identify generic verbs relevant to this DSS.
Yes

Translate the verbs into commands, and vice versa.
Yes

Check out public libraries for off the shelf routines.
No-prior study determined no GMI scheduling packages existed.

Set priorities for implementing commands for version zero.
Yes- autoload of orders

Support first, extend later. Yes

Deliver version zero quickly and cheaply.
No-4 months

a. Evolve a complex DSS out of a simple version zero
Yes

b. Version zero is intended to establish value and to sell itself. Yes

Pick a good user who: Yes

a. Has substantial knowledge of the task,
Yes

b. Has intellectual drive and curiosity,
Yes

c. Will take the initiative in testing and in evolving version zero, and Yes

d. Enjoys being an innovator. Yes

. Recognize data management, rather than commands, as a main constraint.
Only until data and knowledge base were defined in Lisp, them commands became the main constraint.

. Remember that Brooks is right - programming is 10% of the effort. No

. Know your user at all times. Yes

. Rule 11 may be restated in several ways:

a. Programming is 10% of the effort
No

b. If you want to build a product that will stand by itself, recognize the time and effort needed
Yes- substantial

c. Version zero can be built in weeks."
No

Acceptance Criteria: Expert's opinion

Project Completion Process/Procedure/Cut-off
None

Post Implementation Review: None

VI THE DESIGN REPRESENTATIONS

	Final Prototype:
Scheduling Model represented as:	graphical representation of work orders loaded into weekly plant and contractor capacity
Systems Model	1 Lisp program
User Interface and interaction	Commands with graphical representation of work orders and plant capacity.
Systems Integration	None
Management level supported by system	
Operational	Yes
Tactical	No
Strategic	No
Degree and characteristics:	
Tools	Commands
Status Review	Graphical
What-If	Command initiated
DBMS Representations:	
Structures	Lisp
Relationships	Lisp-relational
Knowledge Representations	
Conceptual	Merged with DBase
LISP	Data/Knowledgebase
Prolog	None

Main system model features:

-menu for entry/display/alter
No-Commands

-menu of items for controllable and non-controllable variables.
No

-illustration of non-controllable variables over a time period.
Yes

-pair wise comparison of alternatives
No

-a working set and a reference set interchangeable and re-accessible.
Yes

-function menu by phase of the decision process
No

-shallow hierarchy of functions
Yes

User Interface	
-simple,	No
-responsive,	
-user interaction	Yes
-turnaround time	2 seconds
-user-controlled,	
-menus	No
-mouse commands	No
-object icons	No
-help command	No
-training examples	Yes
-combined operations	Yes
-user construction of combined operations	
-changing defaults	No
-user specification of graphs/reports	Limited options
-flexible,	Yes
-stable,	No
-protective,	No
-self documenting	No
-reliable	No
-input forms/output forms	No
-checkmark selections	No
Standard Interface:	
Lotus	
DEC Terminal Text Menus	Yes
Monochrome, Colour	Monochrome
Keyboard, Mouse	Keyboard
Menu	
Macintosh interface	
Allegro Lisp	Command verbs
Prolog	
Custom designed	Yes
Workstation	Mac II
Connectivity:	None
User Support Acceptance	No
-identification of several decision alternatives,	Yes
-the exploration of these alternatives,	Yes
-the identification of uncertain elements or developments,	Yes
-the assembling of information from a wide variety of sources and decision aids,	No
-processing the appropriate models to execute these with the different alternatives and scenarios considered	No

-to present in a user friendly reporting method the results of these different analyses.
Yes graphs showing performance

============================

	CAASS V1.4:
Scheduling Model represented as:	graphical representation of sales orders automatically batched into work orders loaded into plant and contractor capacity
Systems Model	1 Lisp program
User Interface and interaction	Mouse activated Commands and icon tools with graphical representation of work orders and plant capacity.
Systems Integration	Import of Sales Orders
Management level supported by system	
Operational	Yes
Tactical	Yes
Strategic	Yes
Degree and characteristics:	
Tools	Mouse Icons
Status Review	Graphical
What-If	Mouse activated
DBMS Representations:	
Structures	Mac lists
Relationships	Mac - Pascal
Knowledge Representations	
Conceptual	Merged with DBase Implicit in command and tools
LISP	
Prolog	

Main system model features:

-menu for entry/display/alter
Mouse Commands and Tools

-menu of items for controllable and non-controllable variables.
Yes

-illustration of non-controllable variables over a time period.
Yes

-pair wise comparison of alternatives
No

-a working set and a reference set interchangeable and re-accessible.	Yes
-function menu by phase of the decision process	Yes, batching, loading, adjusting
-shallow hierarchy of functions	Yes
User Interface	
-simple,	Yes
-responsive,	
-user interaction	Yes
-turnaround time	2 seconds
-user-controlled,	
-menus	Yes
-mouse commands	Yes
-object icons	Yes
-help command	Yes
-training examples	Yes
-combined operations	Yes
-user construction of combined operations	
-changing defaults	No
-user specification of graphs/reports	Limited options
-flexible,	Yes
-stable,	Yes
-protective,	Yes
-self documenting	Yes
-reliable	Yes
-input forms/output forms	Yes
-checkmark selections	Yes
Standard Interface:	
Lotus	
DEC Terminal Text Menus	
Monochrome, Colour	Colour
Keyboard, Mouse	Mouse. KB
Menu	Yes
Macintosh interface	Yes
Allegro Lisp	No
Prolog	
Custom designed	Yes
Workstation	Mac II
Connectivity:	Terminal Emulation to MRP system
User Support Acceptance	Excellent
-identification of several decision alternatives,	Yes
-the exploration of these alternatives,	Yes

-the identification of uncertain elements or developments,
Yes

-the assembling of information from a wide variety of sources and decision aids,
Yes-multiple plants

-processing the appropriate models to execute these with the different alternatives and scenarios considered
Limited- capacity modification scenarios are implicitly supported

-to present in a user friendly reporting method the results of these different analyses.
Yes graphs showing performance measures

VII THE RESULTS

1. Status Indicators for Delivery System:
    1. Transition Period — 6 months

    2. Time to Full/Exclusive Use — 6-12 months

    3. Status from start:
        - 6 months. — Scheduler using system-
        - 12 months — "" "" ""
        - 24 months — "" "" ""
        - 36 months — 30 mos since start

2. Performance Indicators
    1. Degree of Use — Full time

    2. Reliance on System — 100%
        1. Believers — All levels of mngt
        2. Non-Believers — -some want enhancements

    3. Accuracy of System
        1. Problem Predictive ability
           Proven
        2. Solution Analysis ability
           Proven

        3. Solution Choice ability
           Proven

Objectives/Degree of Achievement	High
Documentation	Published user manual
Concepts Designed	-Graphical representations of time, capacity, work orders. -Mngt priorities for sequencing and auto batching and loading. -Scheduler/system mouse based user interface , (Please reference CAASS User Manual for full reporting of features designed.)

Value Indicators

1. Customer order delivery improvements
   Excellent

2. Management planning/control improvements
   Excellent

3. Catalyst for other improvements.
   No

4. External Recognition.
   From GMI and ES researchers

Enhancement/Evolution of Systems

1.	Strategic	Yes
2.	Tactical	Yes
3.	Operational	Yes

Limitations Associated with the System.

1.	Organizational Problems	Schedulers solely dependent on CAASS
2.	Technological Limitations	Want colour printer to present graphics to Meetings
3.	Functional Limitations	Enhancement requested for sequential departmental scheduling, and full material availability constraint representation and modelling.
4.	Other Limitations.	Applicability to other GMI companies unproven.

Management Acceptance — Excellent

VIII. COMPARISON OF CONCLUSIONS:

A. Keen and Gambo(1983)

1. The importance of prototyping as a means of definition of requirements, Yes

2. The importance of user learning in terms of the evolution of the system, Yes- the expert learned the type of visual and processes that a computer was capable of performing.

3. The use of "adaptive design" involving close liaison between the user and the designer,
Yes

4. The importance of the user system interface,
Yes

5. The importance of picking a good user,
Yes

6. A development cycle with stimulus coming both from the system and from the users for continued evolution,
Yes

7. The importance of using a development tool or language which can be modified quickly. No

8. The importance of specific user verbs and their correspondence to system commands.
Yes

B. Moore and Chang(1983)

1. The migration of both the system design and the problem understanding over time. Yes

2. Expansion of situation capabilities.
Yes

3. The evolution from initial "soft" capabilities into more firmly designed hard capabilities. Yes

4. The use of the system to mould and shape the user's decision making processes rather than copying current processes.
Yes

C. Gorry and Krumland(1983)

1. Problem evolves from unstructured to structured.
Yes

D. Altar(1980) DSS Types

1. File drawer systems,
2. Data analysis systems,
3. Analysis information systems,
4. Accounting models,
5. Representational models, including simulation models, Yes

6. Optimization models, and
7. Suggestion models. Yes

Stabell(1983)
Decision channelling through the interface architecture that serves to both support existing decision processes and to shift future processes into the more extensive and powerful use of the tools. To accomplish these, suggested features include:
1. presentation form for logical data structures, Yes
2. system defaults, Yes
3. differential ease of transition between different system functions, and Yes
4. the structure of memory aids. Yes

Focus attention on the nature of the decision problem by differentiating between the control variables which define decision alternatives, non-controllable variables that the decision maker cannot control but that affect the desired decision outcomes or decision criteria. Yes

Facilitate the evaluation of alternatives by providing user controlled report or scanning capabilities to facilitate comparison on the basis of multiple decision criteria. Yes

Extend the planning horizon giving default definitions of variables as if they were time dependent to remind the decision maker of possible changes. Yes

Support uncertainty exploration by allowing the simulation of consequences of differences in cause/effect and states of the environment. Yes

Facilitate the integration of the user's subjective estimates allowing him to modify a private copy of data inputs as well as other readily available and objective computer based data. Yes

Facilitate learning by providing functions for recording and revisiting key decision assumptions. In this respect the results of certain decisions should be monitored and where possible indications reentered to indicate the quality of the decision based on the use of the DSS with a given set of variables and parameters. Yes

Carlson(1983)
DSS should provide familiar representations, (eg. charts and graphs) Yes

DSS should support	Intelligence,	Yes
	Design,	Yes
	Choice.	Yes

DSS should provide memory aids   Yes

DSS should help decision makers work in their own idiosyncratic ways.   Yes

DSS should provide control aids which help decision makers exercise direct, personal control.

Yes

IX SCHEDULING MODEL REPRESENTATION

Identification of Model features, scope, and depth.

A. Basic Scheduling Components(Wild 1985, Stevenson 1982, Buffa 1968, Lockyer 1983)

1. Sales Forecasting
    1. Quantitative methods — None
        1. Historical Smoothing models
        2. Predictive models
    2. Qualitative Methods — None
        1. Delphi
        2. Consensus
    3. Planning Horizon Time
        1. Year — (13 months, with zoom to show one day in 5 minute intervals)
        2. Quarter
        3. Month
        4. Week
        5. Day
        6. Hour
        7. Minute — 5 min. is lowest time interval

2. Capacity Planning
    1. Management of Demand Uncertainty for:
        1. No. of Orders — Yes
        2. Work per Order — Yes- styles per order
    2. Stages of Capacity Planning
        1. Average Levels Req'd — Yes
        2. Variations to Average — Yes
    3. Capacity Management Strategies
        1. Adjustment of Capacity — Yes
            1. Capacity Increases — Yes
            a. subcontract — Yes
            b. reduce material content — No
            c. substitute available material — No
            d. increase supply schedules — Yes
            e. transfer from other jobs — No
            f. defer maintenance — Yes
            h. increase work force size — Yes
            i. increase working hours — Yes

            2. Capacity Reductions — Yes
            a. retrieve work from subcontractors — Yes
            b. reduce supply schedules — Yes
            c. transfer materials to other jobs — Yes
            d. advance maintenance schedules — Yes
            e. reduce work force size — Yes
            f. reduce working hours — Yes
        2. Eliminate need for Adjustment — No
            1. Maintain excess capacity — No
            2. Accept loss of orders — No
            3. Deliver late — No
            4. Create inventories — No

Material Acquisition and Control

1.	Material Requirements Planning	No-delivery only

Aggregate Planning and Scheduling

1.	Multiple channels(plants)	Yes
2.	Multiple products-Manufacturing req'ts planning	Yes
3.	Multiple Sales Forecasts	Yes
4.	Multiple Plans	Yes
5.	Activity Scheduling	Yes

Integration of Operations Research Concepts:

1.	Mathematical models		
	a.	Job Shop	No
	b.	Flow Shop	No
2.	Performance Measures		Non-Optimum
	a.	Minimize Tardiness	No
	b.	Minimize no. of tardy jobs	No
	c.	Minimize ave. tardiness	Yes
	d.	Maximize utilization	Yes
	e.	Minimize Work-in-process	Yes
	e.		
3.	Multi Criteria Decision Making		
	a.	Option Evaluation	Yes
	b.	Weighted Criteria	No
4.	Simulation		
	a.	Control Strategy Evaluation	No
	b.	Model of Physical plant	Yes
	c.	Queue Representations	Yes

Appendix B4
FAMS: System Model, Application Model
(Nassr 1985)

VI THE DESIGN REPRESENTATIONS: The System Model

Scheduling Model represented as: Gantt chart model of workorders loaded into machine/dept operations

Systems Model	Display based Gantt chart
User Interface and interaction	Colour graphics, pull down windows, mouse driven
Systems Integration	No integration with MIS MIS reports used for inputs
Management level supported by system	
Operational	Yes
Tactical	Yes
Strategic	No
Degree and characteristics:	
Tools	Yes
Status Review	Yes-Gauges
What-If	Yes
DBMS Representations:	
Structures	Items, processes, resources, work orders, schedules
Relationships	integrated
Knowledge Representation	
Conceptual	Implicit
LISP	None
Prolog	None
Main system model features:	
-menu for entry/display/alter	Yes
-menu of items for controllable and non-controllable variables.	No
-illustration of non-controllable variables over a time period.	Yes
-pair wise comparison of alternatives	No
-a working set and a reference set interchangeable and re-accessible.	Yes
-function menu by phase of the decision process	No
-shallow hierarchy of functions	Yes

User Interface

-simple,	No
-responsive,	
-user interaction	Yes
-turnaround time	2 minutes
-user-controlled,	
-menus	Yes
-mouse commands	Yes
-object icons	Yes
-help command	Yes-limited
-training examples	No
-combined operations	No
-user construction of combined operations	
- changing defaults	No
-user specification of graphs/reports	Limited options
-flexible,	No
-stable,	Yes
-protective,	Yes
-self documenting	Yes
-reliable	Yes
-input forms/output forms	Yes
-checkmark selections	No

Standard Interface:

Lotus	
DEC Terminal Text Menus	
Monochrome, Colour	Colour
Keyboard, Mouse	Both
Menu	Pull Down
Macintosh interface	Similar
Allegro Lisp	
Prolog	
Custom designed	Yes

Workstation	IBM PC-AT
Connectivity:	None
User Support Acceptance	Unknown

-identification of several decision alternatives,
Yes

-the exploration of these alternatives,
Yes

-the identification of uncertain elements or developments,
Yes

-the assembling of information from a wide variety of sources and decision aids,
No

-processing the appropriate models to execute these with the different alternatives and scenarios considered
No

-present in a user friendly reporting method the results of these different analyses.
Gantt Charts

IX SCHEDULING MODEL REPRESENTATION
(derived from Chapter 3)
Identification of Model features, scope, and depth.

A. Basic Scheduling Components(Wild 1985, Stevenson 1982, Buffa 1968, Lockyer 1985)

1. Sales Forecasting
    1. Quantitative methods None
        1. Historical Smoothing models
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    3. Planning Horizon Time
        1. Year
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        3. Month
        4. Week
        5. Day Yes
        6. Hour Yes
        7. Minute

2. Capacity Planning
    1. Management of Demand Uncertainty for:
        1. No. of Orders No
        2. Work per Order Yes, in total by Delivery date

    2. Stages of Capacity Planning
        1. Average Levels Req'd No
        2. Variations to Average No

    3. Capacity Management Strategies
        1. Adjustment of Capacity Yes
            1. Capacity Increases Yes
            a. subcontract Yes
            b. reduce material content No
            c. substitute available material No
            d. increase supply schedules No
            e. transfer from other jobs No
            f. defer maintenance Yes
            h. increase work force size Yes
            i. increase working hours Yes

            2. Capacity Reductions
Yes
            a. retrieve work from subcontractors
Yes
            b. reduce supply schedules No
            c. transfer materials to other jobs
No
            d. advance maintenance schedules
Yes

e. reduce work force size
Yes
f. reduce working hours
Yes

2. Eliminate need for Adjustment	No
1. Maintain excess capacity	No
2. Accept loss of orders	No
3. Deliver late	No
4. Create inventories	No

3. Material Acquisition and Control

1. Material Requirements Planning	No-

4. Aggregate Planning and Scheduling

1. Multiple channels(plants)	Yes
2. Multiple products-Manufacturing req'ts planning	Yes
3. Multiple Sales Forecasts	Yes
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5. Activity Scheduling	Yes

B. Integration of Operations Research Concepts:

1. Mathematical models

a. Job Shop	No
b. Flow Shop	No

2. Performance Measures	Non-Optimum
a. Minimize Tardiness	No
b. Minimize no. of tardy jobs	No
c. Minimize ave. tardiness	No
d. Maximize utilization	Gauges
e. Minimize Work-in-process	Yes
e.	

3. Multi Criteria Decision Making

a. Option Evaluation	Yes
b. Weighted Criteria	Yes

4. Simulation

a. Control Strategy Evaluation	Yes
b. Model of Physical plant	Yes
c. Queue Representations	Yes

Appendix C

Application of Expert Systems to Capacity Planning for Garment Manufacturers

G. Sawatzky and J. Peterson 1990

Application of Expert Systems to Capacity Planning for Garment Manufacturers

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Abstract

A specific application of expert system methodology to a capacity planning system for the garment manufacturing industry is described. An overview of the development process for the expert system prototype is described with emphasis on the role of rapid prototyping in relation to knowledge acquisition. In addition, a description of the prototype is given. This prototype constructs long term schedules for a manufacturing line considering the constraints of due dates, resource capacity and raw material availability. One important area of human expertise targeted for automation is the knowledge for making decisions about which constraints should be relaxed to minimize the cost of solving a scheduling problem.

1.0 Introduction

In recent years there has been a lot of activity in development of expert systems. In many cases this term is used rather freely. An expert system could be defined as a system whose performance is equal to or exceeds that of an expert in some domain. This level of performance needs to be verified with extensive testing. These systems should also exhibit features such as explanation facilities and capability to allow a user to modify problems parameters for "what if" analyses.

Currently, expert systems are being developed for a wide variety of applications. One important area which is currently receiving considerable interest is production scheduling [1,2,3,4,5]. A scheduling system is a system which generates an assignment of tasks to resources without violating any of the constraints of the resources and tasks. A record of this assignment can be called a schedule. A type of scheduling that is of concern here is the long term capacity planning that is required to prevent severe capacity problems. This problem is especially difficult in the dynamic garment manufacturing industry where demand for products is often highly unpredictable and the reliability of raw material suppliers is low. The garment industry was selected because of scheduling systems development by Peterson with a local garment manufacturer in 1983-84. This work led to Peterson's Phd research on expert scheduling systems [7] and eventually to the system described in this paper.

The basic structure of any scheduling system includes a database of the products, customers, customer orders, work orders, suppliers, raw material inventory, a model of the production facilities, a representation of the resource and task constraints, and finally a set of algorithms and heuristics to achieve the scheduling function. In order to find an acceptable schedule, often one or more constraints must be modified [3]. The knowledge used to make these decisions is an example of expertise that is usually not incorporated into MRP scheduling systems. The different ways that companies and industries make these decisions also reflect their special operating environments.

Scheduling systems are typically designed to be used by various personnel of an organization. The people which use the system want to have a system which is easy to understand and operate. This is partially achieved by requesting and providing data in clearly understandable formats. Thus, the user interface of a scheduling system requires careful design. With ever declining computing costs there are many more possibilities in designing the user interface with modern user interface tools and concepts such as mouse sensitive graphic objects, icons, dialog windows, scrollable text windows, mouse sensitive tables (spreadsheets) and pull down menus. The user interface of the system is critical since a poorly designed interface could be the reason for the failure of a system.

This paper describes a prototype capacity planning/scheduling system which was jointly developed by the authors. One of the goals of this prototype was to capture some scheduling expertise. In addition, the use of modern user interface tools for a scheduling program was explored. Based on the experiences of developing this prototype and using it as a reference, development of a commercial scheduling system targeted for garment manufacturers was initiated.

This report is organized as follows: First a discussion of the knowledge acquisition process is given followed by a description of the prototype features. Testing of the prototype is described and details for further development of the prototype and new commercial version are described.

2.0 Knowledge Acquisition/Representation and Prototyping

Expert systems are often developed from one or more sources of expertise. This leads to one of the biggest difficulties of developing an expert system, the process of identifying the expertise and then finding a good representation for it. This prototype is based on knowledge from two types of human experts, as well as, appropriate reference material. The two types of expertise were general scheduling knowledge from a consultant and more specific expertise from a scheduler.

Knowledge acquisition can be accomplished with a number of different techniques. Some of these techniques are interviews with experts, observation of experts, representation of knowledge found in reference material and automated knowledge extraction techniques from a set of examples. For the prototype, the interview process was the main method of knowledge acquisition. For the development of the commercial system, additional knowledge is obtained from user feedback and from comments that result from presentation of the system to potential clients who are typically senior production managers with years of experience.

Due to the exploratory nature of this research, it was decided to create a flexible environment to test and develop new ideas for scheduling. A brief description of the resulting prototype is given later, but first a few words about the role that prototyping played for knowledge acquisition and representation. It was found that a working prototype, no matter how limited, was very useful for clarifying perceptions of how things needed to be represented internally and externally, and of course how scheduling functions were achieved. This process is illustrated in Figure 1. Knowledge acquisition interviews without a prototype could easily launch discussions about high level functionality that was in reality a long way off. However, discussions centered around the prototype tended to be much more focused on more immediate concerns. Both of these types of discussions are important and one would provide material for the other.

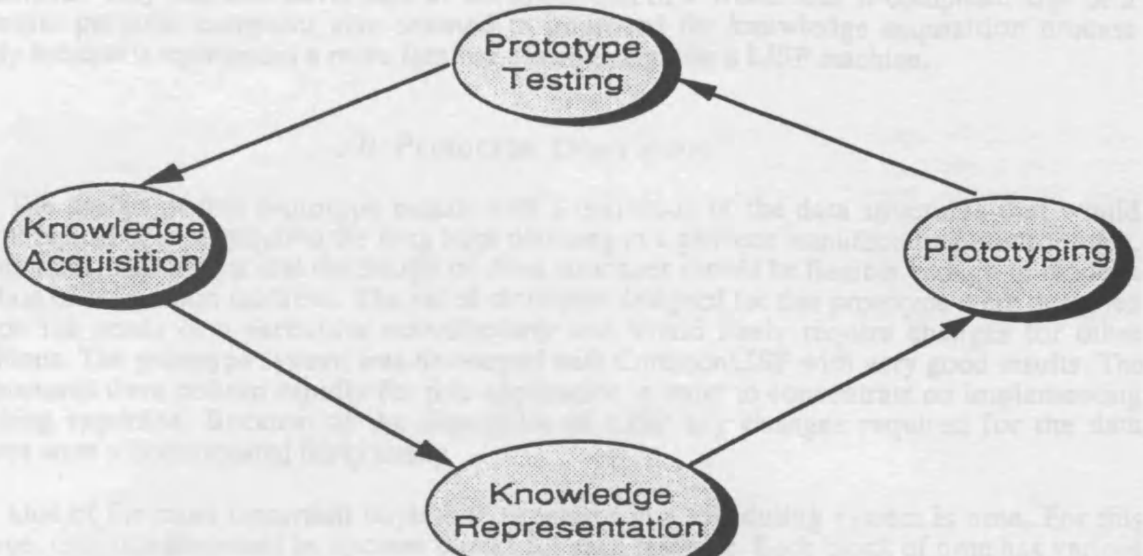

Figure 1 Rapid Prototyping process

An important design decision that must be taken before beginning the prototyping phase is to choose the basic system architecture. An expert systems is often implemented as a pattern directed inference engine. Such a system contains a set of rules each having a pattern and an action. Whenever the pattern of a rule matches information in the database, it is put on an agenda. The highest ranking rule on the agenda is allowed to perform its action on the system. This process continues until no rules can act and no changes occur in the information base. This model, shown in figure 2, is used as the basis for the prototype. Currently, most of the effort has been directed towards the design of the information base, actions, and the user interface. Automatic triggering of actions by matched patterns will be implemented in later versions of the system, when the scheduling knowledge is better understood.

From initial interviews of our scheduling experts, it seemed that there rarely is a clearly defined optimal response to situations found in the scheduling domain. The action chosen often depends on underlying strategies and operational philosophies of a particular company. For example, one of the most common problems to be solved by the system is deciding which constraints need to be relaxed in order to assign unassigned work orders. Depending on the situation, the scheduler has a number of alternatives to choose from. For example, one could either use additional overtime, increase capacity, schedule the order for late production, reschedule other orders, or subcontract an order to solve an under capacity problem. It is felt that the knowledge required to make these decisions can be extracted and then represented within the system so that these decisions can be made automatically. In fact, a pattern directed inference engine would seem to be an appropriate representation to apply to this type of knowledge.

Various development tools were used for the prototyping process. Initially, ART (Automated Reasoning Tool) was used on a Symbolics. With this powerful hybrid environment it was possible to develop a skeleton prototype with graphic displays in approximately six weeks. This time period, however, does not include design meetings. During prototyping it was found that data aggregation, database actions and user interfacing was best done with procedural LISP code rather than with rules. Rules are better for expressing higher level knowledge about constraint relaxation after most of the initialization work is done. Eventually, is was possible to use CommonLISP only and take advantage of the lower cost of a Macintosh II computer. Use of a mainstream personal computer also seemed to improved the knowledge acquisition process probably because it represented a more familiar environment than a LISP machine.

3.0 Prototype Description

The design of this prototype began with a definition of the data structures that would represent typical objects required for long term planning in a garment manufacturing environment. One important issue here is that the design of these structures should be flexible enough to model a large class of production facilities. The set of structures designed for this prototype were designed based on the needs of a particular manufacturer and would likely require changes for other applications. The prototype system was developed with CommonLISP with very good results. The data structures were defined rapidly for this application in order to concentrate on implementing scheduling expertise. Because of the flexibility of LISP any changes required for the data structures were accommodated fairly easily.

One of the most important objects to represent in a scheduling system is time. For this prototype, time is represented as discrete blocks for each resource. Each block of time has various attributes whose values can be set. For other applications a more continuous representation of time might be more appropriate.

A simple priority based scheduling algorithm that can assign work orders backwards from their due date or forward from their earliest start date was implemented. The algorithm assigns work orders which can be either a part of a single customer order, a single customer order, or a collection of customer orders for the same product. The algorithm will not violate any constraints of either the resource or the work order. If an order can't be assigned it is left as unassigned. Any constraints which require relaxing will be left to another process, either the expert or a set of rules that emulates the expert.

The user interface was not a high priority during the first prototype phase. However, for knowledge acquisition by observation of an expert user of the prototype, a new version with a clear, robust, and easy to use interface is required. The first prototype has been ported to the Macintosh environment with extensive use of the standard Macintosh user interface tools and conventions. Sample screens from the program are shown in figure 3.

4.0 Testing and Results

In order to test the prototype, data from a local garment manufacturer was entered into the system. This data set consisted of approximately 1000 customer orders, from 100 customers for about 100 products. The system was able to schedule these orders in less than a minute. Currently, the user can modify the constraints of the resources and work orders interactively. The commercial version of the system is successfully being used by the same manufacturer for long term scheduling of some of its production lines.

5.0 Future Work

Improved versions of the commercial system will continue to be developed based on feedback from users and continued research. Its use will be carefully observed in order to capture knowledge on how constraints are modified in various scenarios. Additional knowledge can be expected from future interviews with production managers from other manufacturers. Once new knowledge has been identified, it will be incorporated into the system. It is felt that this process can continue for a number of years before the system would be considered complete.

6.0 Conclusions

It is shown that the expert system approach can create scheduling systems which will have better performance and acceptability than strictly algorithmic scheduling systems. Production scheduling systems of the future will blend the best of known scheduling algorithms with knowledge acquired from the best schedulers. The user interface design of scheduling systems must adopt new user interface tools available and apply them based on a deeper understanding of the human computer interaction that occurs in a production scheduling environment. Finally, it was found that a rapid prototyping process facilitated the knowledge acquisition and representation process.

References

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[7] Peterson J., "Expert Scheduling Systems", Ph.d thesis (in preparation).

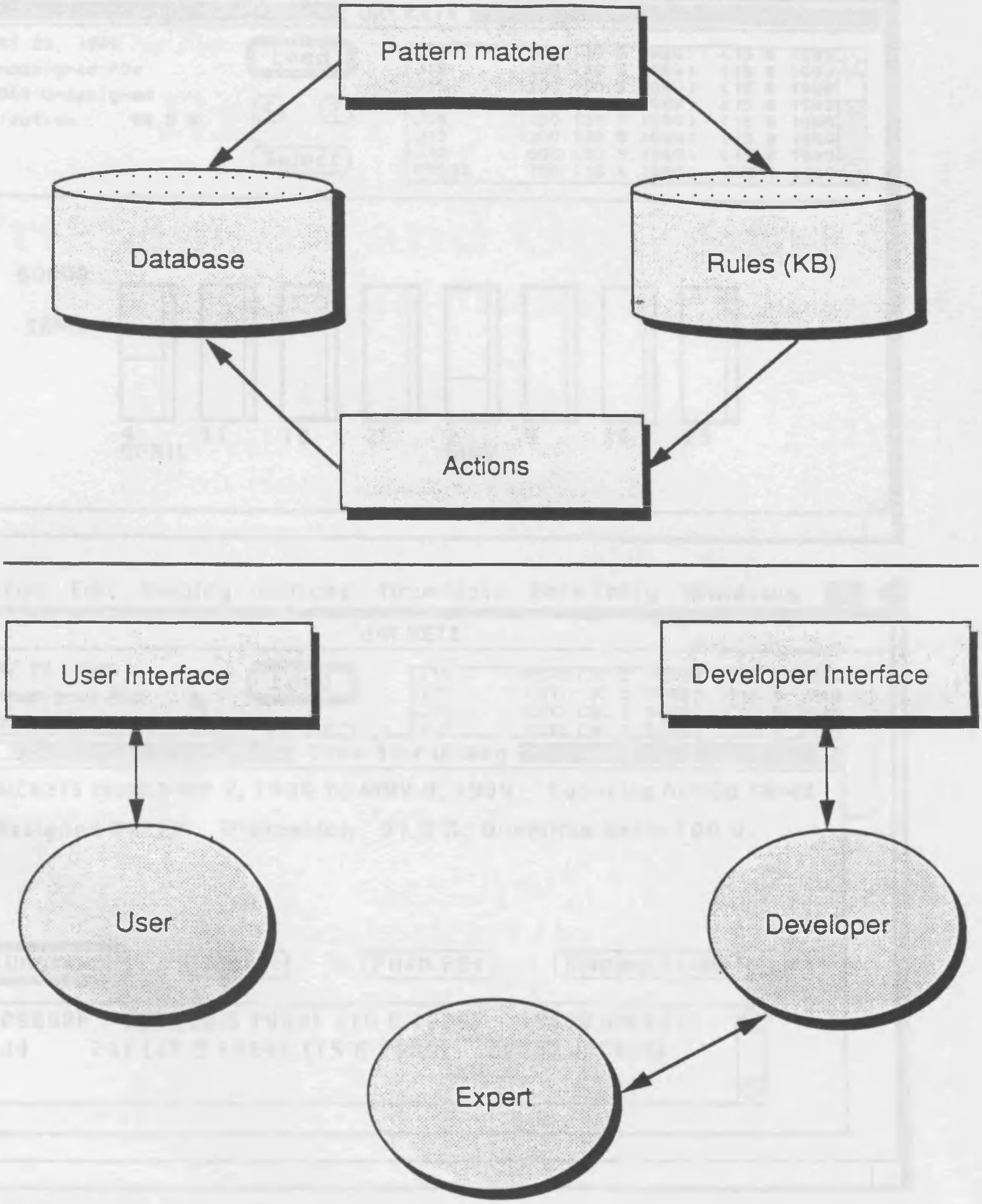


Figure 2 Basic Structure for an Expert Scheduling System

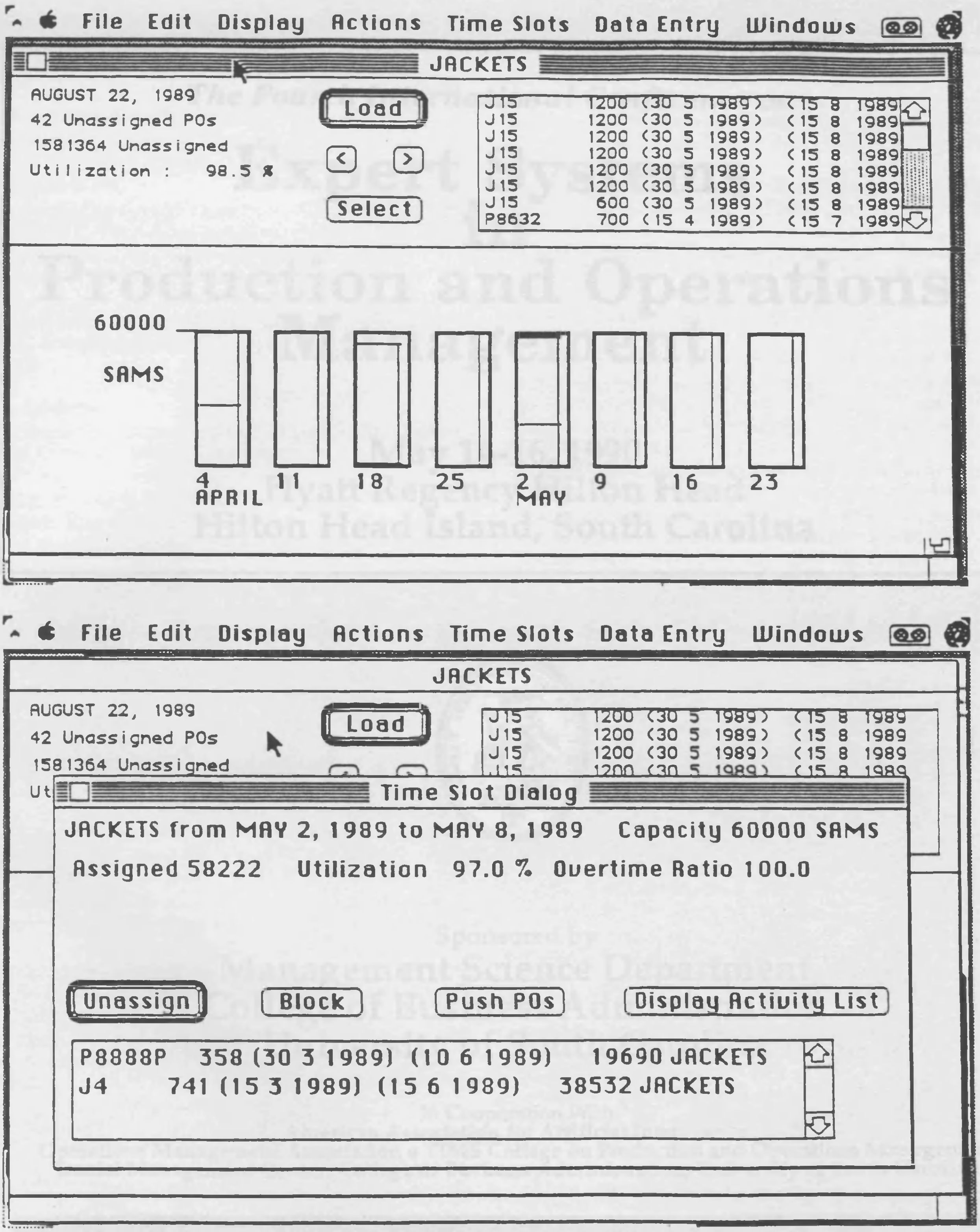


Figure 3 Sample screens from the prototype

The Fourth International Conference on

Expert Systems in Production and Operations Management

May 14-16, 1990
Hyatt Regency Hilton Head
Hilton Head Island, South Carolina

Sponsored by
Management Science Department
College of Business Administration
University of South Carolina

In Cooperation With
American Association for Artificial Intelligence
Operations Management Association o TIMS College on Production and Operations Management
Daniel Management Center, College of Business Administration, University of South Carolina

Conference Program

Monday, May 14

Keynote Address
Flexible Computer Integrated Manufacturing in the Global Marketplace. D. Bruce Merrifield, American Electronics Association and Chaired Professor at The Wharton School

Session M-1: Production Scheduling I
Integrating AI/OR/Database Technologies for Production Planning and Scheduling-Thomas E. Baker, Chesapeake Decision Sciences, Inc.
Production Scheduling through Distributed Simulation-Roy P. Pargas and John C. Peck, Clemson University
Common Sense Scheduling for Manufacturers: Finite vs. Infinite Scheduling-Richard T. Lilley, ProfitKey International, Inc.

Panel Session M-2: *An Expert System Called CHARLEY*-Lawrence C. Emerling and Bruce E. Winkler, General Motors Corp.

Luncheon Address
(How) is AI Impacting Manufacturing?, Mark S. Fox, Robotics Institute, Carnegie Mellon University

Session M-3: Expert Systems in Distribution Management: The Sara Lee Experience
Introductory Remarks- Chuck Chambers, President, Sara Lee Direct
The Application of Expert Systems in Management of Quality at Sara Lee Corp.-Brooke Saladin andCharles Chambers, Wake Forest University
Search and Imitiation Strategies for First Time Users of Knowledge System Technologies: The Sara Lee Experience-Herb Schuette and Pamela E. Smith, Wake Forest University
First Steps in the Use of Expert Systems in Distribution Management : The Sara Lee Experience-Pamela E. Smith and Eileen B. Cooke, Sara Lee Direct
Expert Systems Development at Sara Lee: The User Perspective-John Craig, Brian Rainey, Laura Phail , and Craig White, Sara Lee Direct

Panel M-4: AI and Production Scheduling
Stu Barret, Texas Instruments; Ivan Johnson, Carnegie Group; Barry Fox, McDonnel Douglas

Tutorial M-5: *Introduction to AI/ES:Fundamentals and Applications*- James M. Ragusa, University of Central Florida

Session M-6: Neural Networks
Teaching a New Dog Old Tricks-Examining Neural Networks as a Basis to Build Adaptive Expert Systems for the Manufacturing Environment-David T. Cadden, Quinnipac College
A Hybrid Neural Network / Expert System for the Property Casualty Insurance Industry-Colin O. Benjamin, Joseph Bannis and Dan Medley, University of Missouri-Rolla

Session M-7: AI and Production Scheduling I
Synthesis of Schedules using Heuristic, Constrained-Guided Search- Stig Arff and Geir Hasle, Center for Industrial Research, Oslo
Expert Systems for Plant Scheduling Using Linear Programming:-Kenneth F. Reinschmidt, John H. Slater and Gavin A. Finn
Overview of CORTES: A Constrained-Based Approach to Production Planning, Scheduling and Control- Mark S. Fox and Katia P. Sycara, Carnegie Mellon University

Tutorial M-8: *Introduction to AI/ES: Fundamentals and Applications* (cont.)- James M. Ragusa, University of Central Florida

Tuesday, May 15

Session T-1: AI Production Planning and Control I
A Knowledge Network for Planning and Control of Refinery Industry: UNIK-R Project Experience- Jae K. Lee, Sang B. Oh, Min S. Suh, Min Y. Kim and Yong U. Song, Carnegie Mellon University
Intelligent Process Control in Glass Container Production-Cihan H. Dagli and Juan E. Vidal, University of Missouri-Rolla
Expert System and Operational Production Planning in the Manufacturing of Chemicals: A Hybrid Approach-William J. Selen, Ruud. M. Heuts and Willem Van Groenendaal,Boston University-Brussels

Session T-2: AI and Production Scheduling II
A Hybrid Algorithmic and Knowledge-Based Implementation for Workcenter-Based Production Scheduling-Martin H. Czigler and Clinton R. Whitaker, David Sarnoff Research Center
A Knowledge-Based System for Flexible Assembly Scheduling-Suranjan De and Anita Lee, University of Iowa
Commonizing Scheduling: Artificial Intelligence and other Technologies in Generic Roles-George H. Brown, Compuware

Tutorial T-3: *Verifying and Validating Expert Systems*—Daniel O'Leary, University of Southern California

Session T-4: Production Planning and Control II
Application of Expert Systems to Capacity Planning for Garment Manufacturers-Gordon Sawatzky and J. Peterson, National Research Council of Canada
Planning in a CIM Environment: Research Towards a Constraint-Directed Planner-Robert E. Frederking and Lin Lawrance Chase, Carnegie Mellon University
MAPLEX: Material Planner Expert Advisor-Joseph G. Walls and Gilbert Parent, University of Southern California
Knowledge-Based Parameter Configuration in the MRP Package COPICS-P. Mertens and Th. Wedel, University of Erlangen-Nuremberg

Tutorial T-5: *Verifying and Validating Expert Systems (cont)*-Daniel O'Leary, University of Southern California

Session T-6: AI and Production Scheduling III
Learning Scheduling Rules for FMS from the Optimal Policy of User-Based Semi-Markov Decision Processes-Yuehwern Yih, Purdue University
Protection Against Uncertainity in a Deterministic Schedule-Whay-Yu Chiang and Mark S. Fox, Carnegie Mellon University
An Expert Battle Management Decision Aid Applied to Dynamic Scheduling of Incoming Nuclear Threats-John S. Rogers and Dion Boyett, University of Alabama-Huntsville

Panel Session T-7: KBS Applications in Manufacturing & Operations: The IBM Experience
Dennis Pierce, IBM Lexington; Rufus White, IBM San Jose; Bill Drent, IBM Palo Alto

Lunch
Seaside Luncheon Buffet

Session T-8: AI Application Areas

Expert Systems for Electric Utility Scenario Planning- K. Caleb Chan and L. Laszlo Pallos, Georgia State University

The Development and Implementation of an Expert System for Service Operations-James R. Nolan, James Welch and James Tully, Siena College

TEST+: The Extension of an Application Shell for Turbine-Generator Diagnosis-Bruce M. McLaren and Gary S. Kahn, Carnegie Group, Inc.

Session T-9: Strategic Issues and AI

A Hybrid Approach to a Generic Diagnosis Model-Won Y. Lee, Suraj M. Alexander and James H. Graham, University of Louisville

Automatic Graphics Presentation for Production & Operations Management Systems-Steven Roth and Joe Mattis, Carnegie Mellon University

CIM: A Review of Porter's Generic Business Strategies-Assad Tavakoli, Fayetteville State University

Panel Session T-10: Production Scheduling II

Intelligent Shop Scheduling and Control- John Kanet,Clemson Univ.; Heimo H. Adlesberger,Tech. University of Denmark; Hermann H. Havermann, AHP Havermann & Partner GmbH-Munich; Joachim von Lippe,Siemens -Munich; Jack C. Peck, Clemson University; A. W. Scheer, Univ. of Saarland-Saarbrucken

Session T-11: Implementation Techniques

Knowledge-Based Applications: Avoiding the Mistakes-H. E. Fargher, P. Elleby and A. Elleby, University of Reading, U.K.

Expert Systems Technology Transfer -Teaching Approaches to Accelerate Industrial Adoption-Orlando E. Katter and Walter A. Wolf, Winthrop College

Knowledge Bases as a Tool for Improving Manufacturing Operations-Charu Chandra and Sant Arora, Thermo King

On the Subject of Chips, Expert Systems and Businesses-Tai Sugimoto, International Chip Corp.

Session T-12: AI and Strategic Issues in Production

Intelligent Networking: Towards Integrating the Manufacturing Enterprise-Michel Roboam and Mark S. Fox, Carnegie Mellon University

A Hierarchic Knowledge-Based Approach to Facility Location-Colin O. Benjamin and Chamnong Jungthirapanich, University of Missouri-Rolla

Panel Session T-13: Production Scheduling II

Intelligent Shop Scheduling and Control (cont.) -John J. Kanet, Heimo H. Adlesberger, HermannH. Havermann, Joachim von Lippe, Jack C. Peck, A. W. Scheer

Dinner Address

Knowledge Based Systems in Manufacturing; A Success Story -Quinton O'Neil, Manager, Corporate Manufacturing, Expert Systems Project Center, IBM, San Jose, Ca.

Wednesday, May 16

Session W-1: Expert Systems Development Techniques

Incorporating Object-Oriented Methodologies in the Construction of Expert Database Systems-Dion Boyett, University of Alabama-Huntsville

A Logical Framework for Developing an Intelligent Expert Database System-Subashish Guha and James G. Wilson, University of South Carolina

Natural Language Interface to Databases-Asheesh Kumar, University of Alabama-Huntsville

A.I. Scheduling: A Decision Support Tool for Knowledge Elicitation- P. Lecocq and E. Falkenauer, Center for Scientific Research, Brussels

Panel Session W-2: Production Planning and Control III

Manufacturing Planning and Control Systems: Past, Present and Future-Tom Reif, Ingersoll Engineering; Joseph Schengili, Numetrix; John Kanet, Clemson University

Session W-3: Specialized Applications

The Integration Analysis Filter: A Software Engineering Technique for Integrating Old and New-Geoffrey A. Howe and Geof Goldbogen, Rensselnear Polytechnic Institute

WASTE-TECH-A Knowledge Based System for Hazardous Waste Treatnment Technology Selection-Richard P. Mignogna, K. Scott Perrin, Charles M. Rastle and Craig M. Young

Expert System for Dispatch of Virtual Machines- J. Parmeswaran and Roanald W. Chorba, Clarkson University

Session W-4: Production Planning and Control IV

The Role of Expert Systems in Encouraging Teamwork/ Ownership while Reducing the Dependence on the Scheduling/ Knowledge Domain-Christopher A. Oleksy, Dow Corning Corporation

Distributing Production Control- Katia P. Sycara, S. Roth, N. Sadeh and M. Fox, Carnegie MellonUniversity

Variable and Value Ordering Heuristics for Activity-Based Job-Shop Scheduler-Norman Sadeh and Mark S. Fox, Carnegie Mellon University

Session W-5: Production Maintenance Expert Systems

Expert Systems-An Effective Tool in the Maintenance Environment-David M. Rhyne, Fluor Daniel

Development and Deployment of Maintenance Expert Systems at Honeywell-Steve Pine, Honeywell, Inc.

Conference session locations and times are listed on the back page in Conference at a Glance

Conference at a Glance

Sunday, May 13

6:00 pm - 9:00 pm	Conference Registration	West Registration Desk
	Hospitality Reception	Ballroom J

Monday, May 14

7:30 am - 8:30 am	Continental Breakfast	Ballroom J
7:00 am - 5:00 pm	Conference Registration	West Registration Desk
8:30 am - 5:00 pm	Exhibits Open	West Foyer
8:45 am	Welcoming Comments	Ballroom GHI
9:00 am - 10:00 am	Keynote Address	Ballroom J
10:00 am	Break	West Ballroom Foyer
10:15 am - 12:00 pm	Session M-1: Production Scheduling I	Ballroom D
	Panel Session M-2: Expert System - CHARLEY	Ballroom H
12:00 pm - 1:30 pm	Luncheon Address	Ballroom J
1:30 pm - 3:00 pm	Session M-3: Expert Systems in Distribution Management: The Sara Lee Experience	Ballroom H
	Panel Session M-4: AI and Production Scheduling	Ballroom G
	Tutorial M-5: Introduction to AI/ES	Ballroom I
3:00 pm	Break	West Ballroom Foyer
3:15 pm - 4:45 pm	Session M-6: Neural Networks	Ballroom H
	Session M-7: AI and Production Scheduling I	Ballroom G
	Tutorial M-8: Introduction to AI/ES (contd.)	Ballroom I
Evening	Dinner (On Your Own)	

Tuesday, May 15

7:30 am - 8:30 am	Continental Breakfast	West Ballroom Foyer
8:30 am - 5:00 pm	Exhibits Open	West Foyer
8:30 am - 9:45 am	Panel Session T-1: AI Production Planning and Control I	Ballroom G
	– Session T-2: AI and Production Scheduling II	Ballroom H
	Ballroom Foyer	
	Tutorial T-3: Verifying and Validating Expert Systems	Ballroom I
9:45 am	Break	
10:00 am - 11:30 am	– Session T-4: Production Planning and Control II	Ballroom D
	Tutorial T-5: Verifying and Validating Expert Systems (cont)	Ballroom I
	Session T-6: AI and Production Scheduling III	Ballroom H
	Panel Session T-7: KBS Applications in Manufacturing & Operations: The IBM Experience	Ballroom G
12:00 pm - 1:30 pm	Seaside Luncheon Buffet	BASSHEAD DECK
1:30 pm - 3:00 pm	Session T-8: AI Application	Ballroom H
	Session T-9: Strategic Issues and AI	Ballroom G
	– Session T-10: Production Scheduling II	Ballroom I
3:00 pm	Break	Ballroom Foyer
3:15 pm - 4:45 pm	Session T-11: Implementation Techniques	Ballroom H
	Session T-12: AI and Strategic Issues in Production	Ballroom I
	– Panel Session T-13: Production Scheduling II (contd.)	Ballroom G
7:00 pm - 9:00 pm	Dinner Address	Ballroom J, West Hall

Wednesday, May 16

8:30 am - 12:00 pm	Exhibits Open	West Foyer
8:30 am - 10:00 am	Session W-1: Expert Systems Development Techniques	Ballroom G
	Session W-2: Production Planning and Control III	Ballroom H
	Session W-3: Specialized Applications	Ballroom I
10:00 am	Break	Ballroom Foyer
10:15 am - 11:45 am	Session W-4: Production Planning and Control IV	Ballroom H
	Session W-5: Production Maintenance Expert Systems	Ballroom G

Conference Organization

Conference Planning Committee

Kenneth Darby-Dowman, Polytechnic of Central London
David Dilts, University of Waterloo
Donald Falkenberg, Industrial Technologies Institute
Geof Goldbogen, Rennselaer Polytechnic Institute
Thomas Kehler, IntelliCorp
John Kelly, Arthur Anderson & Co.
Karl Kempf, Intel
Jae Kyu Lee, Carnegie Mellon University
James Ragusa, University of Central Florida
Daniel Rasmus, Western Digital
Steven Pine, Honeywell
Kaylan Singhal, University of Baltimore
Mona Yousry, AT&T Bell Labs

Conference Chairman
Robert Markland, University of South Carolina
Conference Program Chairman
Douglas Durand, University of South Carolina
Conference Proceedings Editor
Martin Goslar, University of South Carolina
Conference Program Committee
Timothy Fry, University of South Carolina
Kirk Karwan, University of South Carolina
Gary Reeves, University of South Carolina
Exhibit Coordinators
Allen Corbett, University of South Carolina
Brian Honess, University of South Carolina
Conference Coordinator
Ray Crepeau, University of South Carolina
Connie Crook, University of South Carolina
Subashish Guha, University of South Carolina
Mark E. McMurtrey, University of South Carolina

Management Science Department, College of Business Administration, University of South Carolina, Columbia, SC 29208 (803) 777-7448

Appendix D

Case Study III Exhibits and Testimonials

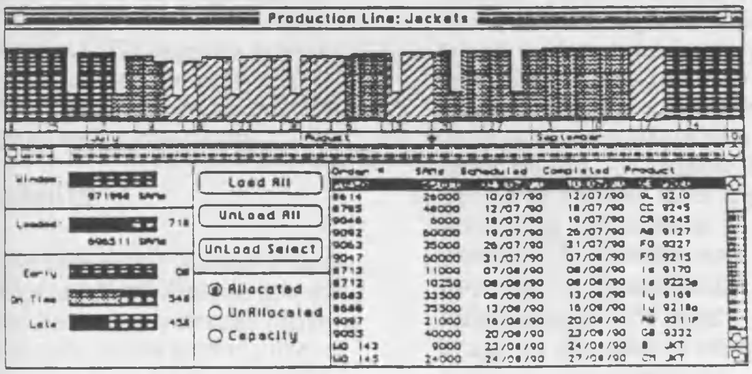
CAASS NEWS

Case Study: Automatic Scheduling in the Sterling Stall Group, Winnipeg Canada

by Mr. Harry Vose
Production Management Consultant

Background

Like most manufacturers, Sterling Stall's season developed very quickly. As a manufacturer of Ladies sportswear, order sizes ranged from 50 units (in various SKU's) all the way to 5000 units. The vast number of styles and fabrics that were involved typifies Canadian companies serving a limited population, and an even more limited number of major companies. As the season unfolded, and fabric availability and customer delivery requirements were "firmed up", it was generally apparent that some extra capacity was required. The problem was compounded by a wide variation in work content within each of the different styles, making the use of "average unit production" a bit "hit and miss" from the production scheduling viewpoint. Up to this point, major customers orders were scheduled based upon SAMs at the beginning of the season, but it was an extremely tedious, time-consuming job that had to be done by senior people because of the complexity of customer service and fabric availability. Often there were delays stemming from customers who because retail sales were in the doldrums, were reluctant to put down hard numbers until the last possible minute. As the situation changed due to fabric availability etc, the Sterling Stall manual scheduling system had to rely more and more on the hit and miss "average unit" approach.



Production Line

A New Approach

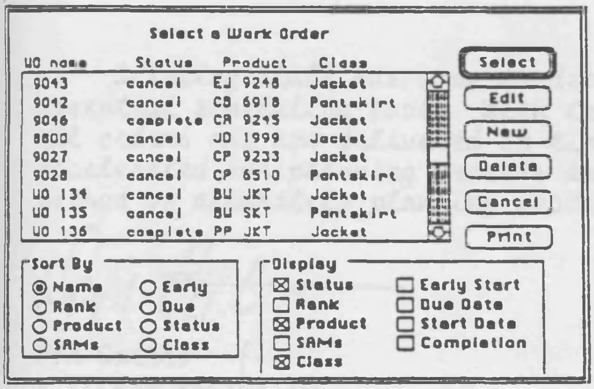
CAASS Inc. invited us to take part in developing an "expert " scheduling system , on Macintosh equipment, that was aimed at de-skilling the scheduling function to the point where basically anyone could do it.

After approximately two years, and countless meetings, a prototype was ready and put into use within the factory alongside the manual system currently in place. The potential of the system was immediately apparent. Gone were the days of staring at a screen consisting of nothing but numbers. The graphics used to schedule both the upcoming season and immediate production were clear, easily manipulated, and gave the scheduler an immediate conceptual picture of the situation.

Automatic functions such as loading the various production lines with unscheduled orders on the basis of fabric availability, customer delivery, and actual work content are accomplished literally in seconds without senior people actually being required. Any problem in capacity or availability jumps off the screen virtually eliminating oversights and mistakes, which in itself is a major advantage.

Playing "what-if" is very simple, the scheduler is able to run through many different permutations at very rapid speed saving the results of each without destroying the original plan.

Creating different production lines (such as contractors) or adjusting current ones because of overtime or holidays is simplicity itself, and making midstream changes in production loading schedules is done in seconds (like everything else).



Work Order Dialog

The purpose of this articles is not to explain what the system can do. A demonstration is necessary for that because of the unique features of the system. Rather, I wish to state what SSG's experiences were and are, in using the system to schedule their numerous production lines as well as contractors.

Results

I have been in this industry in both Europe and North America now for more than twenty years and I have never come across anything like this before from the point of view of ease of use and clarity of information. There are no reams of paper needed, the information is all available on the screen and "output" or printouts are just one piece of paper.

As the system moved into its third season, the results were very positive. In the first season the projected completion date given by the computer in January and the actual completion date at the end of March were only four days apart. In the second season, the difference between actual and projected completion dates was four days also.

Think about this! (from a production point of view). The system was obviously reflecting very closely actual conditions in the sewing plants, and giving hard-nosed, useable information that all production people could use to monitor customer deliveries. As potential problems became evident, several solution options were tested, the best one selected, and a new schedule prepared. This improvement was achieved in a fraction of the previous time spent in scheduling. To consider the system as a money saver in your scheduling department is nearsighted. Consider more importantly, the quality of information and the better decisions that result in better customer service and better manufacturing productivity. That's what happened at SSG, and to my mind, that where the money is!

THE STERLING STALL GROUP

365 BANNATYNE AVENUE, WINNIPEG, MANITOBA R3A 0E5
TELEPHONE (204) 944-0777 TELEX 07-55644

NOVEMBER 30, 1990

COMPUTER ASSISTED AUTOMATIC SCHEDULING SYSTEM (CAASS)

Sterling Stall has come to depend upon the CAASS system as an essential scheduling tool. With the implementation of CAASS virtually all orders are now delivered on time because CAASS has simplified and accelerated our planning process and provided us with a reliable visual method of accurately planning production. We highly recommend CAASS!

Don Cathro
V.P. MANUFACTURING

Brian Babiuk
PRODUCTION PLANNER

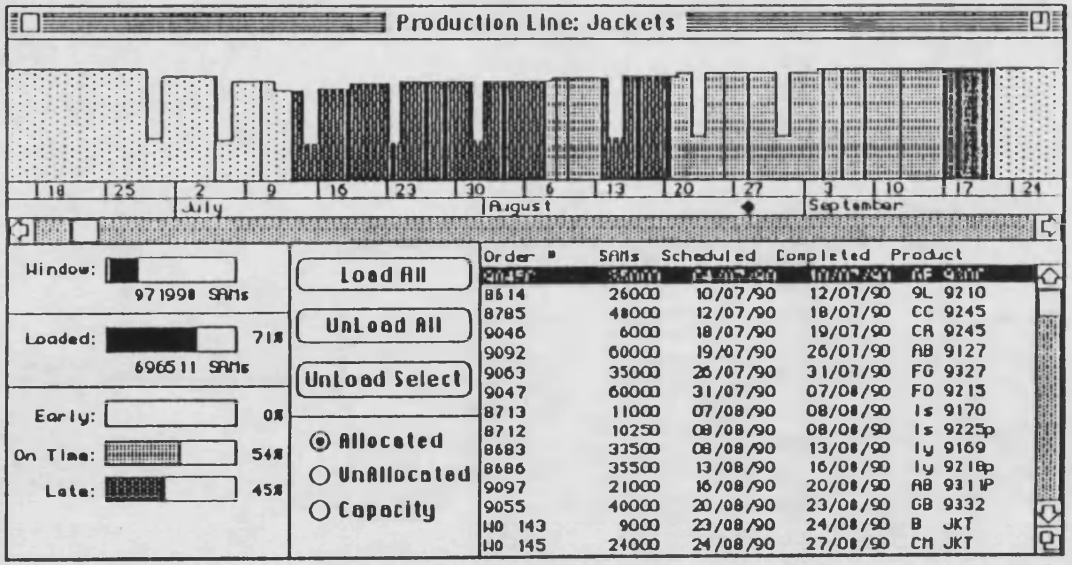
CAASS: COMPUTER ASSISTED AUTOMATIC SCHEDULING SYSTEM

FEATURES OF CAASS

- 1000 Times Faster Than Manual Scheduling
- 100 Times Faster Than Spreadsheet Scheduling
- Automatically Writes Cutting Orders
- Automatically Schedules Cuts Into Production
- Schedules Plants, Lines, Sections, and Work Centers
- Displays Schedules in Vivid Colour Graphics
- Uses Powerful "Game Like" Mouse Actions
- Allows Evaluation of Many Schedule Options

BENEFITS OF CAASS

- Improves Schedule Quality 100 to 1000 Times



- Reduces Scheduling Time by 50% to 90%

- Eliminates Customer Delivery Problems
- Increases Plant Utilization Dramatically
- Increases Porduction Efficiency
- Evaluates Scheduling Options in Seconds
- Simple To Learn and Use
- Improves Management Control of Scheduling Policies

ADVANTAGES OF CAASS

- Improves Customer Relations
- Reduces Production Costs
- Increases Sales
- Increases Profits and ROI
- Eliminates Crisis Management

CAASS

COMPUTER ASSISTED AUTOMATIC SCHEDULING SYSTEM

Functional Description

CAASS stands for Computer Assisted Automatic Scheduling System and is a powerful expert scheduling system software package developed for the garment manufacturing industry. CAASS is a term used to describe a new wave of computer programs designed to increase the scheduler's productivity a 1000 fold over manual methods and 100 fold over PC based spreadsheet systems. CAASS is a new technology, not just an improved old method. CAASS offers features not presently offered on any other form of scheduling system. A compact, intuitive set of commands and tool icons assures ease-of-use and full functionality, and puts you in control of your scheduling environment. The CAASS system embodies extensive use of mouse driven color graphics and concepts from expert or knowledge based systems.

The goal of CAASS is to provide a cost-effective, user-friendly, easy-to-learn product that addresses the needs of senior management, production management and schedulers alike. The industry move towards Quick Response, JIT, EDI, Shorter Fashion Cycles, Private Label Opportunities, increasing competitiveness, and CIM have all highlighted the importance of scheduling.

The cyclical and dynamic nature of the garment manufacturing business means a scheduling tool must be able to respond quickly to changes. By automating as many of the scheduling functions as possible, it is possible to reduce the potential of human error. The ability to detect and help resolve problems such as, late customer deliveries, over or under capacity, aggressive marketing policies, and late fabric deliveries, to name a few in a pro-active manner as opposed to a reactive manner makes CAASS a powerful tool.

The CAASS system provides the scheduler with the flexibility to tailor the system to the organization's needs using a user friendly, intuitive information entry system. For example, management priorities, plans and questions require that different options and scenarios be evaluated by a scheduler. We have found that changing capacity plans and solving production problems require playing "what if" games to evaluate optional solutions.

The scheduling system uses time, activities, and resource parameters to determine the most efficient production line loading sequence of work or cutting orders. The application has a scheduling algorithm as its core and allows the user to enter sales orders, modify scheduling constraints, and manipulate cutting or work orders.

The power of graphics has been applied to represent the data visually and provide the scheduler with a clearer representation of information. One of the advantages of graphics, is that you need only glimpse at them for a moment to understand their meaning.

CAASS provides a user friendly data entry interface to input Product, Material, Customer and Sales Order information into the scheduling database. The Product, Material, and Customer information is displayed in a list format. Sales Order information can be quickly entered through the keyboard or by selecting information from one of the above mentioned lists. Each Sales Order can contain several detail style orders. Once the Sales Order entry process is completed a powerful Batching command is activated to automatically create Cutting or Work Orders. CAASS has a scheduling system that batches and schedules customer orders in seconds and then allows the scheduler to use the incredible power of the Macintosh II to put on the finishing touches.

The Work Orders can then be 'loaded' or scheduled into an appropriate Production Line. This loading process can be done automatically using the LOAD command or manually, one Work Order at a time. The Work Orders are displayed graphically, based on the capacity of the Production Line and the Work Order manufacturing time window. The Production Line window will display the Work Orders in the sequence they are to be produced.

The comprehensive report generating facilities of the CAASS system allows the user to print customer lists, supplier lists, material lists, etc to the screen, a printer, or to a file for later use. A hardcopy of the plant loading sequence can be printed and distributed to the appropriate departments. Along with the printing facilities the CAASS system also has a powerful Import function. The Import command reads order entry data from an ASCII text file and integrates the information into the schedule database. The Import command will display a list of downloadable files, allow the user to browse the information in the file, integrate the information into a schedule, and report abnormalities in the data to the user.

FEATURES OF CAASS

- 1000 Times Faster Than Manual Scheduling
- 100 Times Faster Than Spreadsheet Scheduling
- Automatically Writes Cutting Orders
- Automatically Schedules Cuts Into Production
- Schedules Plants, Lines, Sections, and Work Centers
- Displays Schedules in Vivid Colour Graphics
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ADVANTAGES OF CAASS

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- Reduces Production Costs
- Increases Sales
- Increases Profits and ROI
- Eliminates Crisis Management

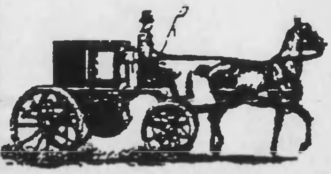
WHY COMPUTERIZED SCHEDULING

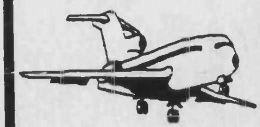
- Visualization
- User Interface
- Graphics Tools for Decision Making
- Computer Aided Scheduling
- Scheduling Skills are Learned,Not Inherited.

FUNDEMENTALS OF SCHEDULING

- Controlling Resources and Schedules
- Budgeting and Cost Control
- Scheduling and Schedule Tracking
- Streamlining With What-If Scenarios
- Balancing Goals and Schedules
- Resources and Budgets
- Importing data
- Report Generation

SCHEDULING METHODS





TASKS	MANUAL SYSTEM	SPREADSHEET	CAASS
Write 100 Cut Orders	10 hours	5 hours	10 seconds
Schedule 100 Cuts	25 hours	3 hours	10 seconds
Rescheule 100 Cuts with Overtime	10 hours	1 hour	10 seconds
Schedule Accuracy Start to End of Season	30%	60%	99%

CAASS
Expert Scheduling
System

Developed By:
CAASS Inc.
Scheduling Innovation for Manufacturers

1067 Sherwin Road, Winnipeg, Manitoba,Canada
R3H 0T8 Phone: 204-694-0185 Fax: 204-924-3094

APPENDIX E
GMI SCHEDULING SYSTEM GUIDELINES

In this appendix the lessons of the cases and the subsequent analyses are presented in a statement of guidelines for GMI management and scheduling system developers.

E.1. THE SETTING

The environment that management creates for the development and implementation of a scheduling system should include the following elements:

1. Firmly committed management, both senior and middle, who have the time and motivation to work with the scheduling system team over an period of 2-4 years to develop and evolve the system
2. A clearly defined scheduling function focused around an experienced scheduler, who has the backing and respect of management and staff.
3. Recognition and acceptance of the magnitude of the task, the phases that will occur, and the financial resources, personal and computer systems required.
4. A project oriented office environment including a private project meeting room for lengthy design sessions, equipped with marker boards, flip charts, and demonstration computer equipment.
5. A recognition that the project is a strategic, long term effort requiring long term planning and isolation from the operational emergencies of the GMI until the initial version has been completed.
6. Establish a small project team of the scheduler, a senior system designer/knowledge engineer and 1 or 2 programmer-analysts/knowledge programmers.
7. Create and maintain a positive project atmosphere with the expectation that the project will continue for a minimum of 2-3 years.

In addition to these findings of this study the Information Technology(IT) literature identifies many requirements for IT success(Montezami 1986, Lucas 1975).

E.2 DESIGNING THE SYSTEM

The design methodology recommendations include the following:

1. Do not begin until the environmental and organizational requirements identified above have been established.
2. Establish regular weekly meetings of 3 hours as a minimum, allowing for periods when more then 1 meeting per week will be required.
3. Select a powerful graphical user interface hardware-software system to develop the system, preferably with development software that allows rapid prototyping or evolutionary development.
4. Employ the design representation guidelines described in the subsequent sections.
5. Identify the scope and interfacing requirements of the system.i.e. scheduling functions and MRP linkages.

E.3 THE DESIGN OF THE SYSTEM

Realistically, the perfect system is likely not within the budget of many companies. Thus a development team contemplating the scope of a new system will likely have to select a subset of the recommendations described in this section. The design representations that I believe to be important are:

1. The scope of such systems must begin with consideration of the problem from a senior management perspective. Specific long range strategies with respect to product development and product market directions, as well as financial plans and constraints, must be reflected. Several such management directions are indicated as follows:
    1. Long range product and market strategy.
        - Product mix by product type with ratios between types.
        - Market direction by segment with a statement by segment of whether or not the market is growing, stable or declining.
        - Market objectives by segment in absolute units as well as ratio between segments.
    2. Financial strategy.
        - Annual dollar plans for costs and sales.
        - Seasonal, quarterly and semi-annual dollar plans.
        - All of the above by market segment.
        - All of the above by production and location.
    3. Operational strategy.
        - In-house versus contracted facilities expressed by country and locale within country.
        - Percentage or ratio mix between in-house and contracted production by country and locale.
        - Resource purchases, i.e. raw materials, direction by country and by supplier type with specific units and percentage ratios, i.e. relative and absolute measurements.
        - Labour policy, stable workforce with maximum percentage changes, or
        - Flexibility of labour force allowing for lay-offs and rehiring with percentage changes allowed.
        - Overtime and second shift, absolute and relative measurements.
        - Encouragement of small specialized facilities or large multi-product production plants.
    4. Sales strategy.
        - Sell from stock, i.e. production made to stock.
        - Sell to orders, i.e. production based on made to order.
        - Quoted delivery periods or deliver from stock with x weeks of lead time.
        - Ship complete orders or allow back orders.
        - Ship complete by collection.
        - Customer priorities and preferences.

    These and other management directives are commonly used by scheduling and operational management within a company. They dictate the general environment within which scheduling decisions are made.

2. The short term management policies and goals must also be reflected in a coherent planning and scheduling system. Such short term management goals and policies can be thought of in the same terms as those longer-termed directions identified above. Usually, however, the short term management directions are with respect to specific types of customers and operational decisions such as contracting, and plant choice and preferences.

3. REPRESENT ENTIRE PLANNING PROCESS
A further requirement for such a planning and scheduling system is that the "entire planning" process must be represented. This planning process begins with total financial units and total production units and then is segmented by market segment and product type and eventually, more specifically into the specific collections which are to be produced. Initially, forecasting is based on total units for a given collection and then subsequently further detailed into product types and eventually to specific products. When the selling period begins, then the specific sales are compared to forecasts. Revisions to forecasts must be monitored closely. If a pattern is seen to develop that forecasts are consistently high or consistently low, then the scheduling system should reflect such consistent patterns, although clearly identifying these conclusions to the scheduling personnel.

4. REPRESENT MAIN EVENTS
Another important consideration in the scope of a planning and scheduling system is that all activities which have a bearing upon the successful execution of a plan or schedule must also be monitored. In this respect, the main stages, within which any aspect of a product, its raw materials, and its development and manufacturing, progress through must be monitored. Thus, several of the main events in the development of a collection or series of products should be identified as to their expected occurrence and monitored by the system. Similarly, the acquisition and delivery of raw materials should also be represented in the system with expected occurrences of key events monitored.

5. REPRESENT HISTORICAL EXPERIENCE
The system must monitor historical problems which have occurred or which the system identifies as having occurred. More detail is described in a subsequent section on problem representation. However, at this time, the direction is identified that the system should include types of problems and tendencies which cause production plans or schedules to be inaccurate as a result of external and internal organizational factors.

6. In addition to the foregoing requirements which are related to scope and production related functions, the

production planning and scheduling system should clearly also perform the preparation of plans and schedules, appropriate sensitivity analyses and provide appropriate communication with users to facilitate the effective and efficient communication in both directions.

7. PLANNING AND SCHEDULING ENVIRONMENT

As a result of my intensive involvement with the scheduling personnel, the following operational oriented requirements are identified:

1. The introduction of new tools is accompanied by a rapid evolutionary process. The process, while being somewhat similar to a learning process, is also one of intense creativity. As the scheduler or scheduling personnel learn more about the potential for the new tool or tools, they begin to create better methods for the use of these tools and enhancement of the entire process. Thus, the tools introduced should anticipate the direction of the creative process and through a learning environment, stimulate the users to an advanced direction to more sophisticated features within the system. In this respect, the creative process should be naturally channelled toward the more sophisticated features of the system. The process is one of evolutionary development. The delivery of such an evolutionary system could be achieved through the introduction of new modules or through the user interface facilitating exploration within the system towards the user discovering these advanced features.

2. The system should attempt to manage the overall planning cycle and schedule that is within its scope. In this respect, critical dates and events should be monitored and their anticipated completion identified to scheduling personnel. Upon the receipt of confirmations that such events have occurred or the revised expected dates of completion, a system should make appropriate conclusions concerning the success of future plans and respond with conclusions and appropriate recommendations. This concept is derived from the intensive fluidity of the scheduling environment and the need for the management of critical events, the management of high priority situations, the management of exceptions, the management of important details, the management of problems, the prevention of problems, and the exploitation of opportunities.

3. Within the scheduling environment and consistent with the above concepts of management by priority, it is the concept of consideration of appropriate levels of detail. In this respect, a degree of detail considered or the level of quality of data considered need only be to the level required to achieve an appropriate conclusion. Thus data aggregation, data reduction and

summarization are appropriate. As an example, comparisons of capacities versus expected production demand should be carried out at the highest levels possible according to the type of problem being considered and the extent of the planning horizon. In this respect, certain problems occurring in the long term would be reviewed from the systems point of view with summarized data. As the situation becomes closer, then increasing levels of detail should be considered.

4. An exception to the foregoing discussion on the use of the least level of detail possible is the concept of identifying potential problems at a detailed level. In this respect, a comparison of capacity versus demand at an aggregate level should be augmented with comparison of that demand as it relates to specific bottleneck situations or potential problem situations at a much more detailed level, i.e. specific machine bottlenecks.

5. The dynamic nature of the scheduling environment demands that the user interface be not only extremely efficient and effective but be exciting and create a positive work environment. In essence the system should create, in the user, a desire to continue to use the system as a result not only of the benefits to the organization but of the satisfaction level in carrying out the interaction with the system.

7. MULTIPLE OBJECTIVE TRADE-OFFS

Perhaps the most difficult cognitive process to be represented in an expert systems or a knowledge-based system is the embodiment of a decision faced with both uncertainty and made with a consideration of multiple objectives. The concept of "the marginal rate of substitution" between competing objectives is seen to be the basis upon which a knowledge-based system could more accurately represent an expert's decision making processes. As a means of knowledge acquisition from senior policy makers as well as operational management and schedulers, the concept of pairwise comparison of competing policy and decision objectives appears to have considerable merit. Specifically, the manager/expert could be seen to interact with either tabular or graphic presentations which would facilitate the clear and easy definition of the comparative or relative cost of yielding one objective to another.

This approach could be used to identify specific marginal rates of substitution between objectives. These individual trade-offs can then be evaluated with a composite trade-off analysis being conducted where common objectives can be grouped. In particular, the work documented in this research for the competing objectives illustrates that the cost of yielding various cost factors to "time before delivery dates" identifies the criticality of certain points in time and the necessity that certain events occur at certain times.

8. RANKING METHODS
The importance of ranking different options and preferences is considered in decision analysis. Ranking methods, including ordinal, cardinal, trade-offs and utility functions are concepts which will be useful in the elicitation of implicit knowledge from experts. Similarly, the concept of objective hierarchies, and the use of proxy attributes when a specific attribute cannot be measured, is seen to be meaningful. The causal relationships between an important attribute and other less important attributes which may be easier to measure is seen as a means of establishing decision criteria for the main attribute.
In addition, the concept of "aspiration levels" rather than optimality can also be a useful tool when eliciting management and expert knowledge.

9. USER BEHAVIOUR
The specific cognitive characteristics of the users are considered. Specifically, the concept of problem solving as an evolutionary and interactive process, is identified. The concept that a solution system should adapt to the problem solver's behaviour instead of insisting that it be done a specific way is an important direction.

10. From the viewpoint of senior management control of a solution process, expert systems technology offers the potential that specific solution processes be followed that are consistent with senior management's prescribed and approved methods. At the same time, it would appear that a problem solver needs to be able to evolve in his use of such tools. Perhaps the solution to this contradiction is that the expert system should constrain the methods which a problem solver can evolve through.

11. Another important concept identified is that a problem solver has a finite cognitive ability to deal with the details involved in a problem solution. Specifically, this relates to the evolution of the problem solver and can be seen to result from an appreciation of how the tools can be used in such a manner that the total complexity of the solution continues to increase by virtue of the problem solver's ability to accept that the new tools carry out detailed operations within the overall solution process. Specifically, this can be seen in general with the human cognitive acceptance of the "black box" concept. The human ability to accept, after sufficient proof, that a "black box" does what it is supposed to do, is fundamental to the use of automated systems and, in particular, expert systems.

12. In this respect, the human cognitive ability to utilize

tools (black boxes), once their use is understood and accepted, allows for the growth of individuals as better problem solvers through the use of "black boxes" of increasing sophistication and power. Clearly, in this respect, the challenge of developing expert systems is to develop user interfaces which are not only easy to use but clearly indicate to the user the solution processes involved without the necessity of the user's consideration of the exhaustive detail considered. At the same time, however, the user must have confidence that the solutions are good solutions, otherwise the confidence in the "black box" fails.

Perhaps a fundamental unstated philosophy of expert systems and knowledge engineering strategies is that the "black box" concept of usage by humans does not have a finite upper bound. In other words, through the development of increasingly sophisticated and wider-scoped systems, the "black box theory" suggests that with some conditions the limitation of usage of "black boxes" will never be achieved. While this discussion overlaps philosophical questions, the consideration of the cognitive limitations of users is a potential for a restriction on the degree of sophistication, scope and usage of an expert system. Clearly, further research in this area should be carried out as a potential future project.

12. Within the general field of production/operations management (POM), there are several general requirements that must exist within any proposed system which is directed at solving the production planning and scheduling challenges. These general requirements are reviewed below and more detailed specific requirements identified in separate sections following.
The general requirements which have been identified from the review of the production/operations management literature and its application to this problem are as follows:

1. The planning exercise is a multi-dimensional activity which is repeated several times throughout an organization's various cycles.
   The first dimension considered in the planning activity is that of the number of cycles that planning is carried out for. In this respect, most organizations carry out a planning cycle corresponding to their fiscal year, i.e. a twelve-month period arbitrarily chosen to represent the business activity carried out in one year.

   The second planning cycle is that related to the product development cycle. In this respect, a specific product grouping is planned for throughout the development and execution of that product development cycle.

2. A second dimension to the planning activity is that related to the number of times within a cycle

that plans are constructed, revised, and reviewed. In this respect for the annual cycle, the plans are formulated prior to the fiscal year, at the beginning of the fiscal year, perhaps quarterly throughout the year, and finally reviewed at the end of the year. Through the product development cycle, plans are constructed at the beginning of the cycle, and at various stages throughout the cycle.

3. A third dimension to the planning activity carried out within an organization is that related to the level of detail involved in each planning activity or planning session. In general terms, the level of detail is lesser at earlier planning activities and considerably more detailed at later planning activities as the execution of the plan becomes closer. The specific details involved with these different dimensions of planning are viewed in more detail subsequently under specific sub-titles.

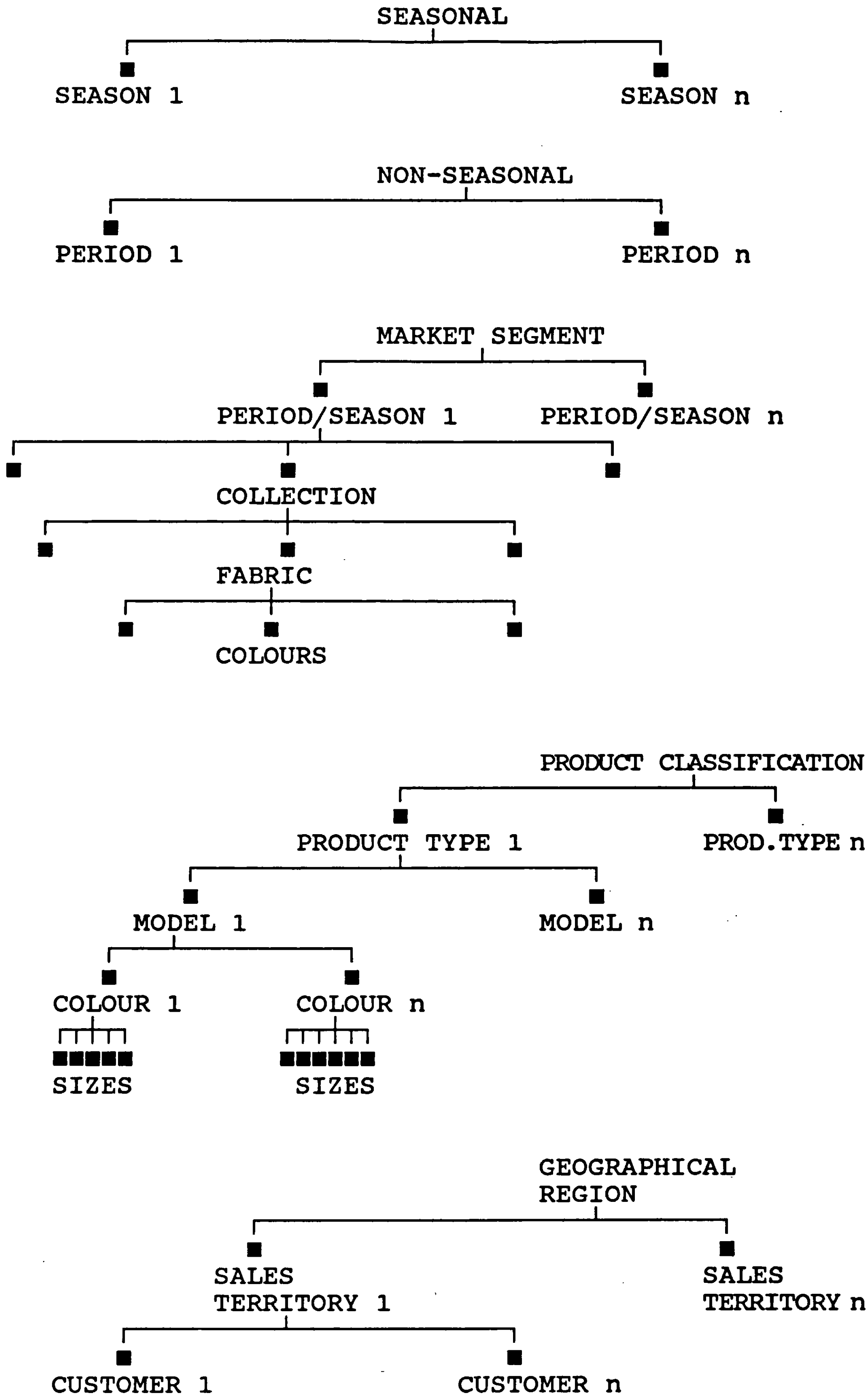
4. The overall planning activity must consider the following general manufacturing functions:
   - Forecasting,
   - Capacity planning,
   - Material acquisition and control,
   - Aggregate planning or scheduling,
   - Plant loading,
   - Line balancing,
   - Production control and monitoring.

   Each of these functions must, in some respects, be represented and the required information related to other functions. In this respect, the data base management systems related to conventional manufacturing requirements and resource planning systems are seen to fulfil most of the basic relationship concepts. The concept of a "shadow or parallel" knowledge base to the data base relationships that was identified is also seen as necessary in the general representation of this problem. Each of these considerations is now identified in more detail with respect to the specific sub-functions involved in the manufacturing operation.

13. SALES FORECASTING

In the detailed review carried out in this research concerning the types of sales forecasting and financial planning carried out in this industry, it was determined, that due to the fashion nature of the business, the applicability of the quantitative methods was limited. While this point could be argued, it is not the purpose of this research to discuss this question at this time. Rather, based upon the present approach to managing these businesses, the sales forecasts are seen to be largely determined on the basis of senior management judgemental viewpoints. These viewpoints are interpreted into financial plans, initially at a general level, and then subsequently in more detail. The specific structure of the financial planning and the planning cycles that are carried out which result in sales forecasts and eventually committed sales demand are illustrated in Figures E.1 attached. Figure 1 illustrates the concept of the different levels of detail that forecasts or plans are established for. Figure 1 also illustrates the different cycles that plans are prepared for. Figure E.1 illustrates the specific types of plans and forecasts leading to the actual specification of customer demand through customer orders.

Figure E.1
Planning and Forecasting Taxonomy



14. The challenge in designing a general architecture with a solution of planning and scheduling problems for the garment industry is seen by this researcher as being a series of decisions such as the one faced at this time. Specifically, the decision at this time is whether or not the extensive and exhaustive detail identified in Figures 1 and 2 are essential to the preparation of a production plan and schedule and whether or not these should be considered to be necessary elements of the general architecture for the production planning and scheduling expert system. The resolution of this decision and final choice of the level of detail to include in this system, I concluded as follows: The system must be capable of handling or processing the types of plans and forecasts identified in Figure E.2. However, the system must also be capable of handling less than the exhaustive list of details and cycles identified. Specifically, only those plans which the management of the company believe to be of fundamental importance should be input to the system, thus if the management and scheduling experts of a given company identify that only one annual plan is relevant and one product development plan is necessary, then the system should be able to function with only those as input. Realistically, it is my viewpoint that one initial or general plan by product cycle is essential and subsequently, only where deviations or changes are identified of a significant nature, will it be necessary to modify the plan. In addition, however, the plan must eventually be identified to the system at the level of detail most appropriate for the subsequent capacity and resource requirement identification. This would typically be at the model or model color level. Again, however, the system must be able to function at whatever appropriate level of detail it is given by the user.

Figure E.2: Planning/Forecasting Cycles Related to Information Detail

INFORMATION DETAIL	FORCAST UNITS: $$$	FORCAST UNITS: UNITS	FORCAST UNITS: PERCENT	PLANNING HORIZON: 12 MONTH	PLANNING HORIZON: FISCAL YEAR	SEASONAL	MONTHLY	PRODUCT CYCLE TIMING
1.BY MARKET SEGMENT	x	x	of total	x	x	x		FISCAL
2. BY COLLECTION	x	x	segment			x		COLLECTION CONCEPT
3. BY FABRIC TYPE		x	collectn			x		
4.BY FABRIC		x	collectn			x		FABRIC CONCEPT
5.BY COLOR		x	fabric				x	
6.BY PRODUCT CLASS. -GENERAL		x	fabric type			x	x	MODEL CONCEPT
7.BY PRODUCT CLASS. -DETAILED		x					x	SELLING PERIOD
8.BY MODEL		x					x	PRODUCTION PERIOD
9.MODEL-COLOR-SIZE		x					x	
10.BY MANUFACTURING CATEGORY		x				x	x	DELIVERY PERIOD

The implication of this "design decision" is that throughout the system the appropriate level of detail and approximation must be clearly related from one function to the next so as to accurately represent the relationships.

15. CAPACITY PLANNING

Capacity planning is seen as the immediate result of the preparation or revision of any planning or forecasting activity. This requirement is essential. The capacity planning analysis activity is seen as being divided into two fundamental steps.
These being:

1. The identification of the required capacity at appropriate levels of detail corresponding to the specific related plan or forecast.
2. The identification of available capacity as per existing or available facilities, and the resulting analysis of the "capacity demand" versus "capacity supply".

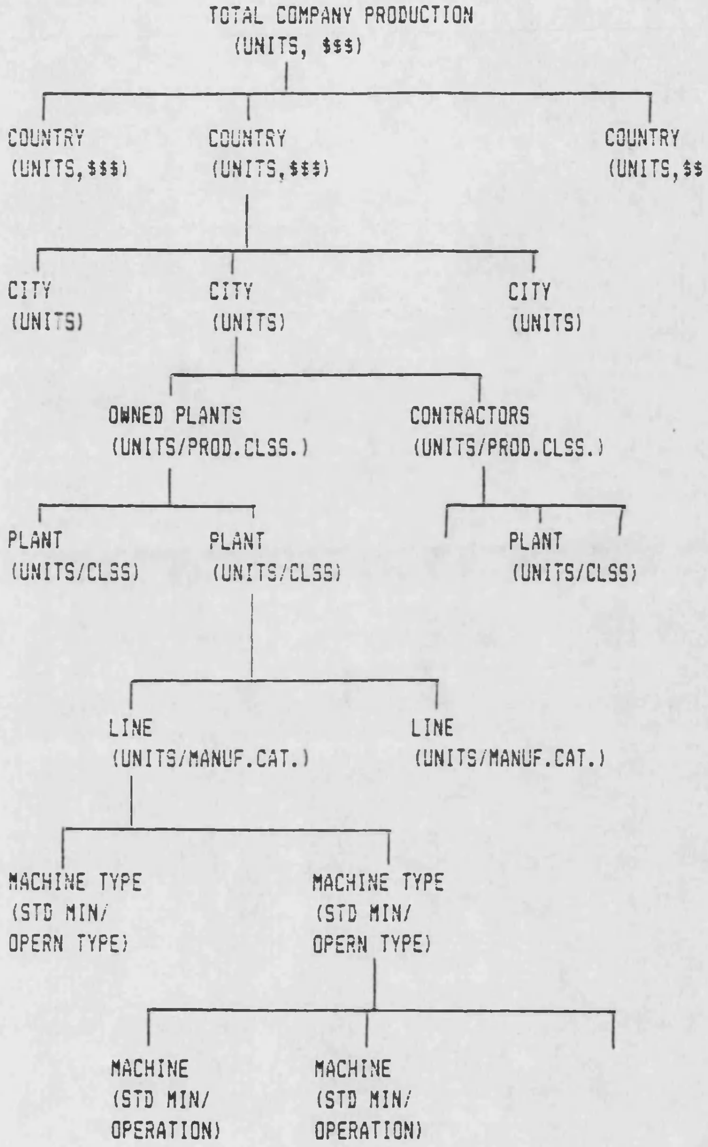
This analysis is carried out at the appropriate level of detail related to, not only the level of detail within which the plan and forecast is identified, but also at the appropriate level of detail within which the capacity facilities are defined. In order to carry out this analysis, it is necessary that each representation of a unit of completed production be identified as to the production requirements or capacity requirements for the production of that unit. Once this is identified, then given the appropriate period of time within which that production is anticipated, the calculation of capacity demand can be easily prepared. The representation of the appropriate level of capacity required, based upon the type of forecast or plan prepared, is illustrated in Figure E.3. Clearly, the more detail involved in the specification of the plan or forecast, the more detail the requirement for capacity can be specified. At the specific level of detail of "model-color" the requirement for capacity can be expressed as a detail list of specific operations and equipment required for the completion of each one unit.

Figure E.3: Capacity Demand by Plan Detail Level

CAPACITY DEMAND EXPRESSED AS:	DETAIL LEVEL OF PLAN			
		PRODUCT CLASS'FCN		MANUF
	FABRIC	GENERAL	DETAILED	CATEGORY
UNITS	✓	✓	✓	✓
TOTAL STD MINS			✓	✓
CUTTING MIN. SEWING MIN FINISHING MIN.	✓	+		✓
MACHINE GROUP MINUTES				✓

16. The second aspect of capacity planning, the identification of available capacity and its comparison to requirements, requires that the capacity available for production be identified clearly to the system. In this respect, as with prior considerations identified, the capacity should be definable at a variety of levels depending upon the level with which the management of the organization thinks appropriate to a particular problem. An illustration of the capacity taxonomy of a typical organization, although exhaustive, is illustrated in Figure E.4. The appropriate level of detail, within which that capacity can be identified, is also illustrated for each capacity level.

Figure E.4: Capacity Taxonomy



17. As a result of the level of detail that the original plan and forecasts is defined at and the corresponding specification of the capacity required at that level, analysis of available versus required capacity can be carried out. The assumed third element involved in this comparison is obviously the time period within which the required units must be produced.

18. Depending upon the level of detail specified, a capacity analysis will be carried out at either a unit level which assumes that total capacity within the prescribed production requirement is available or at the standard allocated minute or dollar value of the production for a given unit. If the plan is specified at the level of manufacturing category, then further identification of specific equipment or equipment groups and specific types of operations can also be specified. Eventually, when the specific detailed operations breakdown is known, then detailed analysis can be conducted. One of the weaknesses of conventional MRP II systems is the requirement that all production demand be specified at the detailed operations level. (Peterson 1988)

19. The analysis of capacity "required", versus "available" is typically done in a graphical fashion illustrating the required demand over time versus the available capacity (Cantaluppi 1984, Fox 1986, Malko 1983, Nassr 1985). From an expert systems viewpoint, the resolution of capacity problems is one of the most fundamental decisions which an expert must consider. A number of factors determine the available options that an expert can use to resolve capacity problems. Specific capacity problems can usually be divided into under capacity or over capacity situations. In each case, a number of options exist which the expert scheduler may use for the resolution of either problem. As identified by Wild (1985), when demand exceeds capacity, the following options can be considered:
    1. Use of contractors,
    2. Reduce material content,
    3. Substitute more readily available material,
    4. Increase supply schedules,
    5. Transfer from other jobs,
    6. Defer maintenance of equipment,
    7. Increase work force size,
    8. Increase working hours.

    Although not all options are necessarily applicable to the industry, these are seen to be at least a subset of the type of options which must be allowed for in the general architecture.

20. In the event that demand is less than the supply of the capacity, then Wild (1985) suggests the following options:
    1. Retrieve work from sub-contractors,
    2. Reduce supply schedules,
    3. Transfer materials to other jobs,
    4. Advance machine maintenance schedules,

5. Reduce the hours worked by short shifts or holidays,
6. Lay off or transfer staff.

Again, these represent a subset of the types of options which must be left available within the general architecture of the system.

21. From the viewpoint of the general requirement for the architecture of the expert scheduling system, it is necessary that the above options exist plus the capability of adding other options as they may be deemed appropriate for either situation. In this respect, I identify other options that are used in under or over capacity situations. Specifically these can be categorized as follows:

A. Over capacity situation (capacity is greater than demand)

1. Perform as a sub-contractor for other manufacturers,
2. Identify short term market opportunities utilizing readily available materials,
3. Arrange specific model adaptations for individual customers on a one-time basis,
4. Remodel or re-equip existing facilities for new products or new methods.

These and other methods will be identified as specific management options which the system must allow.

B. Under capacity situation (demand is greater than capacity)

1. Renegotiate delivery dates for specific customers and/or products,
2. Re-prioritize products and collections on the basis of profitability and cancel non-profitable or less profitable products,
3. Within the concept of increasing work force size and/or working hours are the sub-options of requesting overtime hours on a regular basis,
4. Working second partial shifts,
5. Weekend work shifts. These and other options will be identified by future users of systems generated within the overall architecture identified in this research.

22. The identification of the above options and their relevance to a given situation cannot be carried out without consideration of the overall management philosophy, direction and policies or strategies of a given organization. Therefore, a further requirement of the general architecture is that it accommodates the identification of such senior management policies, directions, strategies, etc. Such policies and strategies must relate to the identification of which options are considered feasible or viable by a given organization. In addition, a means of indicating preferences or pair-wise rankings of all available options must also be identified to the system. In addition, the identification of when such options are applicable must be available for management to indicate their use by product, capacity facility and in given specific time periods. Conceivably other qualifications

on the specific use of a given option may also exist.

23. A further specification required by an organization using such an architecture or system is that specific products be identified as to their type or classification and relate these to specific manufacturing facility requirements. Such a specification is illustrated in Figure E.5. In this respect, each product class can be identified as corresponding to a manufacturing categorization which can further be related to a requirement for specific facilities and/or types of equipment. Following the general philosophy of allowing the user organization to specify only the level of detail deemed appropriate, such product classifications must be allowed at different levels of detail. The corresponding level of detail would be specified for manufacturing categorizations and specific manufacturing facilities needed to perform the production of such models.

24. Consistent with a prior statement of requirement that only critical or important situations be managed, this concept is further illustrated in Figure E.5 to identify and highlight critical operations or critical facilities that correspond to the production of any particular unit at an appropriate specified level of detail by product classification, etc.

Figure E.5: Product Manufacturing Requirements

	--- ACCURACY LEVEL BY FORCAST DETAIL ---					
MANUFACTURING CATEGORIZATION	MARKET SEGMENT	SEASON	COLLECTN	PRODUCT CLASS'N	DETAIL PROD.CLSS	MODEL
GENERAL CATEGORY	AVE %					
-SUB CATEGORY	% RANGE	AVE %	AVE %	% UNITS		
MODEL FEATURE		% RANGE	% RANGE	% UNITS		
MACHINE TYPE			% RANGE	% RANGE	% UNITS	
MACHINE					% RANGE	
OPERATION						UNITS
RESTRICTIONS:						
MUST PRODUCE AT..				X	X	X

25. MATERIAL MANAGEMENT: ACQUISITION AND CONTROL
Within the general concept of materials management there are several areas that require specific representation in the general architecture. These are:

1. The statement of the bill of material requirements corresponding to the appropriate levels of detail identified in the sales plan or forecast. This relationship is identified in Figure E.6.
2. The identification of specific materials and their corresponding suppliers and their corresponding shipping methods. These relationships are illustrated in Figure E.7.
3. The total requirement for individual materials must be identified at the appropriate time when they are required. This requirement results from an analysis of the sales forecast and customer orders.
4. With a knowledge of the required materials and approximate volumes based on appropriate plans, the required time decision points for the various stages in material acquisition can be identified as a result of the knowledge of the sources or vendors of the given type of material. This concept is illustrated in Figure E.8.

In each of the above illustrations, Figures 6, 7 and 8, the system must provide for the specification appropriate to the types of materials utilized by the given organization.

Figure E.6: Bill of Material Specification by Plan Detail

PLAN DETAIL:	MATERIAL TYPE	BILL OF MATERIAL SPECIFICATION SOURCE	VENDOR	UTILIZATION
MARKET SEGMENT	X	X		AVERAGE
COLLECTION		X		AVERAGE
FABRIC TYPE		X		
FABRIC			X	
COLOR			X	
PRODUCT CLASS'N -GENERAL				WITHIN 20%
-DETAILED				WITHIN 20%

Figure E.7: Material--Supplier--Shipping Method Relationship

```
                    RAW MATERIAL TYPE


               FABRIC                                            LEAD TIME
                                                                 CONTRIBUT
               SOURCE                                                :
                  :                                                  :
    :-----------------:-----------------:-----------------:          :
 "LOCAL"       N.AMERICA         EUROPE          ORIENT              :
 (1 WK)        (1.5 WKS)         (3 WKS)         (4 WKS)  <------- SHIPPING
                                                                  TIME

               AVAILABILITY
                    :
    :-------------------:---------------:-----------------:
 IN-STOCK      PLAIN GREIGE      YARN IN-STOCK   SPECIAL ORDER
 (1 DAY)       TO BE DYED        (2 WKS)         (3 WKS)  <------- PRODUCTION
               (1 WK)                                              TIME


               PATTERN
                  :
          :---------:-------:
       PLAIN             PATTERNED
                            :
                   :--------:--------:
               COMMON            ORIGINAL
               DESIGN            DESIGN
               (1 WK)            (1 WK)                   <------- PRODUCTION
                                    :                              DESIGN
                         :---------:-------:
                      IN-HOUSE          CONTRACTED
                      DESIGNER          DESIGNER
                      (2 WK)            (4 WK)            <------- PATTERN
                                                                   DESIGN


                                                          ===============
                                                          TOTAL LEAD TIME
                                                          ===============
```

Figure E.8: Material Management Decision Points

	REQUIRED FOR DELIVERY	ACTUAL COMPLETION
** COMPLETE PRODUCTION BY:	---------	---------
(PRODUCTION TIME)		
** START PRODUCTION BY:	---------	---------
(MATERIAL RECEIVING, INSPECTION, TESTING TIME)		
** RECEIVE MATERIAL BY:	---------	---------
(SHIPPING TIME)		
** SHIP BY:	---------	---------
(MILL SHIPPING TIME)		
** COMPLETE COLORING BY:	---------	---------
(FABRIC DYING TIME)		
** COMPLETE GREIGE PRODUCTION BY:	---------	---------
** ORDER COLORED QNTY BY:	---------	---------
(GREIGE PRODUCTION TIME)		
** ORDER GREIGE QNTY BY:	---------	---------
(PRODUCTION DESIGN TIME)		
** FINALIZE PATTERN BY:	---------	---------
(PATTERN DESIGN TIME)		

26. Once the resulting material management decision points are identified automatically by the system, the management or scheduling experts are then called upon to evaluate these decision points from the viewpoint of whether or not they are achievable given the overall product cycle and especially the accuracy with which the planned sales can be identified. More specifically, if the given collection is difficult to forecast at the fabric or model level by the time specific quantities are required, then the first decision point has been identified as a potential problem. In general terms, the identification of problems with the achievement of the key material management decision points result in the consideration of a finite number of options. These options include the following:

1. Take a partial position of the total expected units or yardage which is deemed to be safe in the given situation. i.e. place a partial order for total requirements or total required units by color.
2. Identify an alternate source of the type of material required which has a lesser decision point time.
3. Identify an alternate material which could be utilized that has a later decision point.
4. Consider utilization of a faster means of transportation, i.e. air freight versus ocean vessel.
5. Establish a least risk production target for the given products utilizing the "problem" material, i.e. fix the quantities to be produced at a reliably saleable level.
6. Pre-sell the specific merchandise to the point where safe forecasts can be determined.
7. Negotiate with the supplier for a later decision time.
8. Commit for staged deliveries over an extended period of time provided the material is seen to be required over several future sales.
9. Take a total position in the material under the assumption that customer demand will be sufficient and/or future collections can be designed to include this material.

Clearly, the choice of which policy or policies to consider in this conflict situation is a subject of senior management policy, direction or strategy. As with other policy concepts, the relative ranking and priority of policies must also be specified in the system.

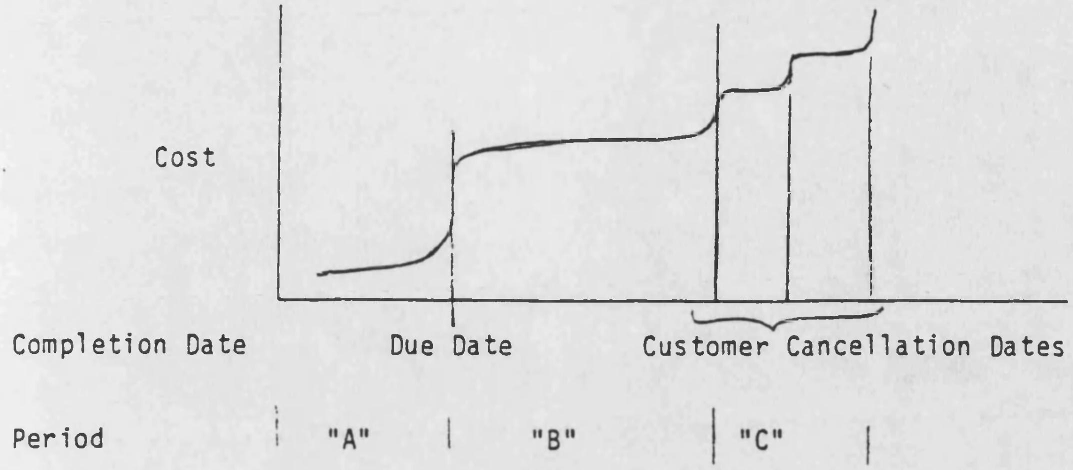
26. A further important option in a material delivery ordering conflict is the possibility of rescheduling the production in such a manner that a particular fabric can be ordered later but still produced on time. In this situation the window of production, i.e. the time of arrival of the material until required production completion is shorter but perhaps can be facilitated within the production schedule. Such a situation likely

requires that the schedule be revised.

27. AGGREGATE PLANNING AND SCHEDULING
Within this function, the primary concept embodied is the selection of an appropriate "activity scheduling method". The selection of which activity scheduling method to utilize is based upon a number of factors. Primarily, the factors most relevant to the choice of method are:

1. Performance measurement(PM) choice, i.e. achieving delivery dates, achieving minimum cost, achieving plant utilization, etc. Once a performance measure has been selected then the then the method to achieve the PM can be made. The identification of the PM is dependent on the time period within the Production cycle as illustrated in Figure E.9, Performance Measure Profile.

Figure E.9
Performance Measure Profile



Description of Performance Measures

Period	Measure
"A"	Minimize number of tardy jobs, which if this can be maintained, then minimize labour cost (maximize machine utilization).
"B"	Minimize average tardiness (past due date)
"C"	Minimize number of tardy jobs where "tardy" is defined relative to customer cancellation dates

2. The activity scheduling method selected will result in the assignment of a job to a manufacturing facility at a specific time.
3. Re-scheduling daily, and weekly, is a reality and thus must be accommodated easily.
4. A common method of activity scheduling is to prioritize orders using Dispatch Rules(Wild 1985) such as those illustrated in Figure E.10

Figure E.10
EXAMPLES OF PRIORITY DISPATCHING RULES (Wild 1985)

Priority (P) based on:

1. Job Slack (S)
   where, S = (Del. Date - Today) - Sum of remaining processing times.
   - poor when delays are associated with each operation
   - processes lowest priority jobs first

2. Job Slack (S) per number of remaining operations (N)
   $P = S/N$
   - process job with lowest priority first (including $P < 0$)

3. Job Slack Ratio

$$P = \frac{S}{\text{Del. Date - Today}}$$

4. Shortest Imminent Operation (SIO): process jobs with shortest processing time first.

5. Longest Imminent Operation - converse of 4.

6. Scheduled Start Date
   - calculate date at which job must start to meet delivery date.
     x = Del. date - (sum of remaining processing times plus a contingency allowance)
   - use reverse scheduling back from delivery dates.

7. Earliest Due Date: process first required job first.

8. Subsequent Processing Times: process first the job that has the longest remaining processing times.

9. Value of Job
   - "To reduce work-in-process inventory costs, process first the job which has the highest value."

10. Minimize Total Float: used by network techniques.

11. Subsequent Operation: Look ahead to the next operation and process first the job that goes to the least critical operation (ie. the operation with the shortest queue).

12. First come - First served: process in order of receipt.

13. Random: "Mix in a hat!"

It would be a partial management policy or decision for a given organization as to which dispatching methods would be utilized in a given situation. At the same time, from the knowledge-based system concept, the system would also be able to determine most appropriate methods to utilize in given situations.

28. In certain situations where multiple facilities exist to perform the same function, the use of assignment rules would also be necessary. The choice of whether or not to use an assignment rule or a dispatch rule would depend upon the physical configuration of equipment or manufacturing facilities available at a given decision point in the manufacturing cycle.

29. As a result of the activity scheduling, a schedule would be prepared which would then be compared to the material management decision points (dates). If all schedule dates had not yet been achieved or had not yet arrived or occurred then the schedule would be seen as a feasible schedule. Once a situation occurs where a material management decision point has been exceeded, i.e. decision did not occur on time, then the necessity exists for revising the schedule according to one of the policy options available and identified by management. Such policy options have been identified in the previous two sections and relate to the rescheduling of work, the identification of additional facilities, or the acceptance of late delivery dates. The difficulty foreseen in this type of scheduling environment is that once a given decision point has been exceeded it is then necessary to reschedule using a forward scheduling process. In other words, those events that have not yet occurred must be defined as to when they will occur and then a schedule prepared for those events from those points into the future. In this respect, the need for both backward scheduling from due dates and forward scheduling from material management decision dates is required.

29. In addition, if a policy option of securing contracted facilities is selected to a specific material management problem, then it is necessary to prepare a schedule for the contracted facilities using a backward scheduling approach. However, in the event that such an approach yields a result which shows to be infeasible because specific decision points have not been completed on time, then once again forward scheduling from the expected occurrence of those decision points would be necessary.

OPERATIONS RESEARCH CONSIDERATIONS

30. The research conducted in this study into the relevant operations research literature clearly identifies that in situations where the performance measure is related to tardiness, then scheduling by delivery date or related
dispatch rules is accepted as the best approach. (Johnson 1967) As was identified in the previous section, the importance of

selection of performance measure is fundamental to the activity scheduling method to be implemented. The appropriate performance measures are illustrated in Figures E.10 a and b.

31. An organization considering the selection of performance measures would need the facility for selecting appropriate performance measures both in consideration of their ranking or hierarchy of objectives as well as relating these to particular time periods and situations which existed at the time of the rescheduling. This implication is that the architecture must support several flexible activity scheduling methods and relate these to policy decisions and strategies identified by an organization's management. Within the various methods of forward, reverse scheduling, dispatching, assignment, etc., it is visualized that future research will identify improved algorithms and heuristics that can be specifically targeted to sub-classifications of problems within those identified in this research. Therefore, the architecture must facilitate this eventuality.

32. INFORMATION TECHNOLOGY REVISITED
A review of the section on information technology identifies several relevant conclusions to the design of the proposed expert systems scheduling architecture. Rather than these conclusions being identified as functional requirements of the system, the conclusions from information technology are more related to the generic adaptation and development of systems in general. These generic requirements relate to concepts of the presentation of information and data, user interaction, system operation, development methodology, implementation methodology, general user expectations and satisfaction criteria, and system interface and integration factors.

33. A potential user organization must be viewed from their position within the various stages of computerization. In this respect, their approach to new technologies would be most favourable if the technology was viewed as an issue intensive technology. In this respect, considerations must be related to the organization's awareness, interest and means of evaluation of potential solution techniques. In addition, the use of trials should be facilitated in order that an organization will complete the implementation and diffuse the resultant solutions. In addition, the importance of identifying and supporting the users, influencers, deciders, gate keepers, planners and sponsors is essential.

34. Broad trends such as increasing use of sophisticated, automated techniques including interactive modelling and planning and computer-aided design and manufacturing through microcomputers and minicomputers is a positive factor for the future acceptance of expert scheduling systems. In this respect, the results of Montezami's(1986) study, although indicating only

5.1% of respondents' desired scheduling and production planning applications, the evolution of these organizations is such that once the fundamental inventory control and accounting applications have been automated their attention will turn to production planning and scheduling. Similarly, the increased use of packages is foreseen to be a supporting trend.

35. The key elements of user satisfaction, accuracy, reliability, timeliness, relevancy, confidence in system, and communication with computer staff must be recognized and appropriately addressed in the future system architecture. Equally important in the context of this architecture is the requirement that the user involvement be encouraged and facilitated.

36. General design guidelines such as keeping the user interface simple, responsive, user-controlled, flexible, stable, protective, self-documenting, and reliable were important for decision support systems. To the extent that the proposed system architecture embody decision support system functionality, these requirements must also be represented. The notion of "decision channelling" to guide the user from elementary functions to more extensive and powerful tools within a system is seen as consistent with the design requirements for this architecture. In this respect, the work by Stabell(1983) is referenced as an excellent prescriptive approach to achieve this end.

37. Further work by Carlson(1983, Keen and Gambino(1983)are also seen as valuable to the methodologies and functional requirements of such a system.

38. The considerable research and literature reviewed in the context of a situation being converted from unstructured to structured highlights the importance for a system architecture to be usable, not only at an elementary level, but also at an advanced level and at the same time facilitate that evolution and direct the evolution as more structure is seen to be usable by an organization.

39. The fundamental importance of the concept of prototyping as a means not only of the definition of requirements but more importantly as a means of evolving structure in an unstructured situation is seen to be an essential requirement of the new architecture.

40. As Martin (1984) has suggested, user developed systems with the aid of "information centre" technical consultants is a model to be supported and encouraged. Conceivably such an implementation model could be supported through an appropriately designed expert system architecture.

41. The conclusion of Specht (1986) that users who face significant amounts of uncertainty need less precise information is an important conclusion which is

supported by the research and has been identified previously as a requirement of this architecture.

42. The use of graphical and colour information presentations are seen as better for approximate decision making than detailed tabular presentations. However, given sufficient time tabular presentations appear to be adequate. With respect to the scheduling environment, consideration of the time pressures suggests the use of graphical and colour presentations.

43. The importance of being able to ask "what if" questions and to simulate various scenarios appears to be a commonly accepted fundamental requirement of decision support systems and will necessarily be a requirement of the proposed architecture.

44. The importance of focusing upon the "decision" itself and the many related processes of decision making and user information are seen as a fundamental foundation in the design of a new architecture. The concept of developing an expert system architecture to parallel the common decision making steps is seen to have considerable power and application if such a paradigm can be implemented. This paradigm also would provide a methodology for knowledge acquisition and knowledge engineering.

45. The analysis of knowledge and expertise into the sub-divisions of core, high rated, applications, functional, and organizational specific were valuable in the conceptual viewpoint of the scheduling knowledge. The concept of viewing knowledge as used in different scenarios was also seen as useful in identifying the scheduling knowledge and expertise. The results of these two approaches to the identification of knowledge and expertise was presented in a prior section and is seen to be valuable and essential to the concept of knowledge representation to this general architecture proposed in this research.

46. The identification of the scheduling knowledge base domain as consisting of knowledge categories, scenarios, and representations of "shadow or parallel manufacturing data base representation", the problem knowledge base representation; related to the product cycle calendar, the senior management preferences and policies as well as long term objectives, plans and goals is seen to be the general requirement of the architecture.

47. One of the most valuable conclusions from this research has been the development of the relationships between decision making, expertise, and problem solving. The development of structures to represent these concepts and the related knowledge are seen as a fundamental building block in the foundation of the proposed system architecture.

48. From the detailed review of the relationships between decision support systems and expert systems, it is my belief that the natural evolution of the system's concept from the original data processing, followed by management information systems, followed by decision support systems results in the eventual evolution into expert systems. In this respect, the concept of an expert system as an "intelligent decision support system" is seen to be correct but not complete. It is seen to be correct in the sense that the concepts of an intelligent decision support system could be embodied in an expert system. However, an expert system or knowledge base system could conceivably also include the fundamental identification and diagnosis of those factors which a decision maker would utilize to conclude that a decision support system could assist in the solution of the problem or in the resolution of the decision. From the viewpoint of the system architecture proposed in this research, the resulting architecture must allow for the use of the decision support system tools either through an expert system or intelligent interface or through the conventional means of using decision support systems. This is so in order that several of the scenarios identified as requests for information can be accomplished within the system. At the same time, the system must embody the diagnostic and judgemental representations of a knowledge base system in order to identify those situations that require the solution of problems or exploitation of opportunities.

49. With respect to the current wisdom in the development of expert systems the prototyping methodology is indicated as being the standard. This may be caused by the nature of the technology being in its infancy with respect to knowledge acquisition and knowledge representation and the lack of a theory on determining the usable scope required in an expert system or in the lack of theories and methods to determine when sufficient knowledge has been designed into the system in order to make it achieve some predefined performance goal. From the viewpoint of the general systems architecture to be proposed in this research, this fundamental reality defines a constraint on what is achievable in this research. Specifically, the architecture proposed will be the initial design guidelines for "Version 0" of the eventual system. The implication of this reality is that either a very specific solution be identified in detail as being the Version 0 with the understanding that it will evolve and likely expand or alternately the general architecture be described within which the realities of the revolutionary, prototyping development could take place. It is my belief that the latter objective of defining a broad architecture based on the requirements identified in this section will be of greater value to future researchers as well as to the application of such techniques to problems of this nature. Further support for this approach can be seen by the reality

that to try and develop the Version 0 of a working system requires considerable "knowledge programming" which is an activity of implementation rather than research.

50. Within the several references researched in the expert systems literature each of those selected has particular concepts or theories which I believe are valid approaches or concepts that should be included in the system architecture. To restate them at this time appears to be redundant and thus the reader is referred to the prior section on expert systems literature for reference to these if desired.

Appendix F

PROBLEM KNOWLEDGEBASE IN PROLOG

Initial Representations of a Scheduling Knowledge Base in Pseudo Prolog

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Introduction

In this Appendix I have attempted to develop the initial representations of various sub-segments of the eventual Scheduling Knowledgebase. These representations are in a Pseudo Prolog and can be easily translated in Prolog.

I have chosen to use my own format of what I call "Pseudo Prolog" since it is much more readable (to me) and I have found that I can produce it with surprising rapidity. To the extent that these representations can easily be converted into Prolog, I have developed a segment of the start of the prototyping exercise towards another version of the Expert Scheduling System.

The initial Knowledgebase(Kbase) representations presented below illustrate the following main conclusions from the thesis:

Problem Representation

Expected Event Kbase

Problem Representation:

This Kbase is represented as follows:

```
INDICATOR  <<-(forsees)--> PROBLEM <--(causes)--> IMPACT(S)
    |                         |
    |                         |<--(alleviates)-->  REMEDIAL
    |                         |                    ACTIONS
    |                         |
    \<<--(prevents)-->> PROBLEM PREVENTOR
```

The Relations are:

pseudo Prolog	**Prolog**
_indicator forsees _problems	forsees(_indicator _problem)
_preventor prevents _problem	prevents(_preventor _problem)
_problem causes _impact	causes(_problem _impact)
_remedy alleviates _problem & _impact)	alleviates(_remedy _problem _impact)

Note: In each of the previous clauses a certainty factor(cff) could also be added to express the liklihood that each assertion is true.

i.e. _indicator forsees _problem with a liklihood of _cff

in Prolog would be:

forsees (_indicator _problem _cff)

The clauses for this Kbase are:

1. _preventor is-indicated-by _indicator if
   _indicator forsees _problem and
   _preventor prevents _problem

2. _impact is-possible-from _indicator if
   _indicator forsees _problem and
   _problem causes _impact

3. _remedy is-needed-for _indicator if
   _impact is-possible-from _indicator and
   _remedy alleviates _problem and _impact and
   _indicator forsees _problem

Enhanced Clauses:

These clauses can be enhanced (as in the prototyping process) by adding the certainty factors and testing for the product of the preliminary cff's to see if it is sufficiently high to suggest that the assertion is true.

To illustrate, consider the prior clauses enhanced accordingly. Each has been written in Prolog notation.

```
1.   is-indicated-by(_preventor _indicator _cfii) if

               forsees(_indicator _problem _cff)  and

               prevents(_preventor _problem _cfp) and

               TIMES( -cff _cfp _cfii)            and

               GT(_cfii .5)
```

Which Means: if the liklihood of the certainty factors of the "forsees" (i.e._cff) and "prevents" (_cfp) when multiplied together to yield "cfii", exceed ".5" then the assertion should be reported upon and the _preventor action should be followed.

```
2.   is-possible-from (_impact _indicator _cfip)  if

               forsees(_problem _impact _cff)     and

               causes (_problem _impact _cfc)     and

               TIMES(_cff _cfc _cfip)             and

               GT(_cfip .5)
```

"Impact is possible from indicator if cfip>.5."

```
3.   is-needed-for(_remedy _indicator _cfin)      if

               is-possible-from(_impact _indicator _cfip)
                                                  and

               forsees(_indicator _problem _cff)  and

               alleviates (_remedy _problem _impact _cfa)
                                                  and

               TIMES(_cfip _cff _cfin)            and

               TIMES(_cfin _cfa _cfin)            and

               GT(_cfin .3)
```

Sample Kbase Entries

Once the prior relations and clauses have been established the actual "knowledge" nust be entered into this Kbase. This knowledge is in the same form as the above relations and clauses.

Specifically we need to establish the knowledge entries for each of

forsees(_indicator _problem _cff)

prevents(_preventor _problem _cfp)

causes(_problem _impact _cfc)

alleviates(_remedy _problem _impact _cfa)

A few examples will illustrate this knowledge.

"Special features in the design of a product have the effect of causing unforseen problems in the sewing and are usually caught at quality control inspection. The result in 90% of the cases is a higher percentage of re-work causes the total time and cost to exceed the standard cost. This happens in approximately 70% of the cases where new or special features are added to a style design."

The specific elements of our knowledgebase can now be extracted.

_indicator(s) (forsees)	special design features, new style features
_problem (causes)	more rework in the sewing lines, higher percentage of rejection
_impact	total cost exceeds standard
	total time exceeds standard
_cff	.9
_cfc	.7

This discussion leads to further analysis of the preventative action and the remedial action.

The problem can be prevented if the designers are made aware of the risk and are given a few options of the type of features that are less likely to cause this problem.

If the new feature must be left on the style then production must be informed early enough that they can engineer specific effecient methods that will eliminate the quality and cost problems. If this is not realistic give the style to a few contractors to bid on and contract it out. If the features are so far from the norm them suggest the style be dropped from the line. If none of the above can be done effectively, then plan for the problem by increasing the standard minutes by 1.25.

The _preventor (prevents)	inform designers with options (cfp=.6)
and	inform production for engineering training (cfp=.5)
	contract out (cfp=.6)
	drop from line (cfp=1)
The _remedy	There is no remedy except to allow for the problem and correctly represent the time as being 1.25 the standard. (cfa=.9)

In the four years of direct experience and participation I approximate that as many as 1000 of such situations could be defined. I have defined over 100 in my working papers alone.

Expected Event Kbase:

A special class of scheduling problems can be related more specifically to a formal activity plan that exists in many fashio and seasonal manufacturers. This plan is a list of activities, somewhat like a project plan that has a critical path as well as key dates and responsibilities for completion.

Although a CPM methodology could be used, it would not provide the knowledge component of what is "really" likely to happen.

In the sense that the database of the activities and the critical path are characteristic of the more traditional systems, this Kbase is the "shadow" of the database, reflecting interpretation of the data.

This Kbase can be segmented into

Part A. Actual Overdue Situations. (called Main Events)

Part B. Possible Overdue Situations

Part C. Situations requiring more investigation and information.

Part A.

Relations:

has-events(_objective _event1 _event2 ... _eventn)

event-due(_objective _eventi _due-date _compl-date)

Clauses:

```
1.    event-overdue(_objective _event _today _late)
                              if

           event-due(event _due-date _compl-date)   and

           SUBT(due-date _today _late)                   and

           GT(0 _late)                                   and

           EQ(0 _compl-date)
```

These events are overdue today.

Part B. Possible Overdue Situations based on information.

Relations:

has-events(_objective _event1 _event2 ... _eventn)

is-evidence(_objective _info _eventi _evdate _cfev)

This means that for this _objective, based on _info is evidence that _eventi occurred on _evdate with _cfev

Clause:

```
suggests(_objective _info _eventi _eventj _exp-date _cfl)

                     if
          is-evidence(_objective   _info   _eventi   _evdate
_cfev)
                     and
          time-between(_eventi _eventj _T _cftb)
                     and
          (a separate relation)

          SUM(_evdate _T exp-date)
                     and
          TIMES(_evdate _cftb _cfs)

          GT(_cfs .3)
```

Part C. Need more information.

as above with cfs < .3

```
investigate(_objective _info _eventi _eventj _exp-date
        _cfl)
            if
    is-evidence(_objective   _info   _eventi   _evdate
            _cfev)
            and
    time-between(_eventi _eventj _T _cftb)
            and
    (a separate relation)

    SUM(_evdate _T exp-date)
            and

    TIMES(_evdate _cftb _cfs)

    LE(_cfs .3)
```

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